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Combustion Modification NOx Controls for Utility Boilers. Volume II: Pulverized-Coal Wall-Fired Unit Field Test

Acurex Corp.
Mountain View, CA

Prepared for

Industrial Environmental Research Lab.
Research Triangle Park, NC

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COMBUSTION MODIFICATION NO_x CONTROLS FOR UTILITY BOILERS

Volume II. Pulverized-coal Wall-fired Unit Field Test

Prepared for

Office of Air Quality Planning and Standards

Prepared by

Industrial Environmental Research
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Research Triangle Park NC 27711

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The report gives methods and results of an environmental assessment test program at Gulf Power's Crist Power Plant, Unit 7. The aim of the program was to measure multimedia emissions changes as a result of applying NOx controls. Emissions of trace elements, organic materials, sulfur species, particulate matter, CO_2, O_2, NOx, and CO were measured. These emissions, under normal and controlled (for NOx) operating conditions were compared. Source operating data were also analyzed to that changes in operating parameters and efficiency could be assessed. Unit 7 is a 1.64 Gg/hr (3.6 million lb/hr) steam pulverized-coal-fired electric utility boiler (500-MW generator output). It is a horizontally opposed, natural circulation, radiant, reheat steam generator with a balanced draft furnace. The unit began operation in 1973. Two degrees of NOx control were tested: the highest level, reducing NOx by 34%, consisted of burners-out-of-service (BOOS) on the furnace rear wall with lowered excesss air levels; and the other, an intermediate level, consisting of BOOS on the front wall only, reduced NOx by 27%. Boiler efficiency was increased slightly while operating under lowered excess air levels. The tests showed that applying combustion modification NOx controls slightly increased particle mean aerodynamic diameter. Most emissions did not change significantly with firing mode.

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COMBUSTION MODIFICATION NO_x CONTROLS FOR UTILITY BOILERS
VOLUME II: PULVERIZED-COAL WALL-FIRED UNIT FIELD TEST

by

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ABSTRACT

This test report describes the methods and results of an environmental assessment test program conducted at Gulf Power's Crist Power Plant, Unit 7. The purpose of the test program was to measure changes in multimedia emissions as a result of applying NO_x controls. Emissions of trace elements, organic materials, sulfur species, particulate matter, CO_2, O_2, NO_x, and CO, were measured. Comparisons of these emissions under normal operating conditions and controlled (for NO_x) operating conditions were then made. Source operating data were also analyzed so that changes in operating parameters and efficiency could be assessed.

Crist, Unit 7 is a 1.64 Gg steam per hour (3.6×10^6 lb/hr) pulverized coal-fired electric utility boiler. It is a horizontally-opposed natural circulation, radiant, reheat, steam generator with a balanced draft furnace. This unit began operation in 1973.

Two degrees of NO_x control were tested on this boiler. The highest level of NO_x control, which achieved a 34 percent reduction in NO_x emissions, consisted of burners-out-of-service on the rear wall of the furnace with lowered excess air levels. An intermediate level of NO_x control, which consisted of burners-out-of-service on the front wall only, reduced NO_x emissions by 27 percent. Boiler efficiency was increased slightly while operating under lowered excess air levels.

The test program concludes that applying combustion modification NO_x controls slightly increased particle mean aerodynamic diameter. Particulate emissions did not change significantly with firing mode. Sulfur emissions did not change considerably with firing mode, however, the percent of fuel sulfur oxidized to SO_3 and SO_4 was reduced with low NO_x firing. Trace element partitioning or organic emissions were not significantly affected by firing mode. Bioassay tests on samples from the highest NO_x control level showed nondetectable toxicity in most tests. However, the small flyash sample showed low toxicity in the Rabbit Alveolar Macrophage test.

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SECTION 1
INTRODUCTION

This report is part of a series of test reports resulting from the experimental testing task of the "Environmental Assessment of Stationary Source NO_x Control Technologies" (NO_x EA) Contract 68-02-2160. The NO_x EA is a 3-year program to: (1) identify the multimedia environmental impact of stationary combustion sources and combustion modification NO_x controls; and (2) identify the most cost-effective environmentally-sound NO_x controls for attaining and maintaining current and projected NO_2 air quality standards to the year 2000.

During the first year of the NO_x EA, a preliminary environmental assessment concluded that emissions and operating data needed to perform adequate process engineering and environmental assessment activities were severely lacking in several key areas. Most noteworthy was the virtual absence of data on noncriteria flue gas emissions and liquid and solid effluents (Reference 1). In response to these identified data needs, NO_x EA field test programs were initiated. Source selection was based on a source/control priority listing developed in the preliminary environmental assessment. These test programs were designed to provide information on changes in emissions and operation due to NO_x controls. The NO_x EA Field Test Program is outlined in Table 1-1.

The test program documented in this report was conducted on Gulf Power's Crist Steam Plant, Unit 7. This unit was selected because it was the host site for long-term corrosion tests conducted by Exxon R&E under an EPA/IERL program. Thus, the NO_x EA tests augmented the Exxon test program to the mutual benefit of both programs. Unit 7 is a pulverized coal-fired electric utility steam generator capable of producing 1.64 Gg steam per hour (3.6×10^6 lb/hr). This unit is a typical horizontally-opposed pulverized coal-fired utility boiler. The unit is also capable of burning natural gas fuel. The unit was made available for testing in the NO_x EA

TABLE 1-1. NO_x EA FIELD TEST PROGRAM

Source Category	Description	Test Points (Unit Operation)	Sampling Protocol	Test Collaborator	Status
Coal-fired Utility Boiler	Kingston #6; 180 MW tangential; twin furnace, 12 burners/furnace, 3 elevations; cyclone, 2 ESP's for particulate control	Baseline Biased Firing (2) BOOS (2)	Continuous NO_x, SO_2, CO, CO_2, O_2 Inlet to 1st ESP: -- SASS -- Method 5 -- Method 8 -- Gas grab (C_1-C_6 HC) Outlet of 1st ESP: -- SASS -- Method 5 -- Method 8 -- Gas grab (C_1-C_6 HC) Bottom ash Hopper ash (1st ESP, cyclone) Fuel Operating data	TVA	Complete, August 1977
Coal-fired Utility Boiler	Crist #7; 500 MW opposed wall fired; 24 burners, 3 elevations; ESP for particulate control	Baseline BOOS (2)	Continuous NO_x, CO CO_2, O_2 ESP inlet -- SASS -- Method 5 -- Method 8 -- Gas grab (C_1-C_6 HC) ESP outlet -- SASS -- Method 5 -- Method 8 -- Gas grab (C_1-C_6 HC) Bottom ash ESP hopper ash Fuel Operating data Bioassay	Exxon	Complete, June 1978

TABLE 1-1. Continued

Source Category	Description	Test Points (Unit Operation)	Sampling Protocol	Test Collaborator	Status
Oil-fired Utility Boiler	Moss Landing #6; 740 MW opposed wall fired; 48 burners, 6 elevations	Baseline FGR FGR + OFA	Continuous NO_x, CO, CO_2, O_2 -- SASS -- Method 5 -- Method 8 -- Gas grab (C_1-C_6 HC) Fuel Operating data Bioassay	New test start	Complete, September 1978
Coal-fired Industrial Boiler	Traveling grate spreader stoker, 38 kg/s (300,000 lb/hr); ESP for particulate control; wet scrubber for SO_x control	Baseline LEA + high OFA	Continuous NO_x, CO, CO_2, O_2 Boiler exit: -- SASS -- Method 5 -- Shell-Emeryville -- Gas grab (C_1-C_6 HC) ESP outlet -- SASS -- Method 5 -- Shell-Emeryville -- Gas grab (C_1-C_6 HC) Bottom ash Cyclone hopper ash Fuel Operating data	KVB	Complete, October 1977
Coal-fired Industrial Boiler	Traveling grate spreader stoker, 25 kg/s (200,000 lb/hr) ESP for particulate control	Baseline LEA + High OFA	Continuous NO_x, CO, CO_2, O_2 Boiler exit: -- SASS -- Method 5 -- Shell-Emeryville -- Gas grab (C_1-C_6 HC) ESP Outlet -- SASS -- Method 5 -- Shell-Emeryville -- Gas grab (C_1-C_6 HC) Bottom ash ESP hopper ash Fuel Operating data Bioassay	KVB	Complete, February 1978

TABLE 1-1. Concluded

Source Category	Description	Test Points (Unit Operation)	Sampling Protocol	Test Collaborator	Status
Oil-fired Gas Turbine	T.H. Wharton Station, 60 MW GE MS 7001 C machine	Baseline maximum water injection	Continuous NO_x, CO CO_2, O_2 -- SASS -- Method 5 -- Method 8 Fuel Water Operating data Bioassay	General Electric	Complete, April 1978
Oil-fired Residential Heating Unit	Blueray low NO_x furnace, Medford, New York	Continuous Cycling	Continuous NO_x, CO CO_2, O_2 -- SASS -- Method 5 -- Method 8 Fuel	New test start with EPA/IERL-RTP	Complete, November 1977

Field Testing Program through the cooperation of Gulf Power Company and Exxon Research and Engineering.

The NO_x EA and Exxon field test program at Crist consisted of a Baseline (normal operation) test and tests under two modes of low NO_x operation. Both low NO_x modes consisted of staged combustion by burners-out-of-service (BOOS). The first mode (BOOS 1) consisted of turning off coal feed to the top row of burners on the front wall only. The second mode (BOOS 2) consisted of turning off coal feed to the top row of burners on the rear wall only. This resulted in a test program of two low NO_x tests and one Baseline test. The test program results, together with Exxon corrosion results, as available, will be used in both process analysis and source analysis modeling, conducted as part of the Environmental Assessment and Process Engineering Task of the NO_x EA. The results presented in this report are an aggregate of data taken under the NO_x EA and Exxon programs.

SECTION 2

TEST SITE DESCRIPTION

The Crist Power Plant is located on the Conecuh River north of Pensacola, Florida. The plant consists of seven boiler turbine-generator systems with a combined output of 970 MW. Units 1 and 2 began operation in the mid-1940's. Unit 3 began operation in the early 1950's and Units 4 and 5 in the late 1950's. Unit 6 began operation in the late 1960's and Unit 7 in 1973. Unit 7 has a rated output of 500 MW.

Crist Unit 7 is a pulverized coal-fired boiler built by Foster Wheeler Energy Corporation. It is a horizontally-opposed, natural circulation, radiant, reheat type steam generator. The furnace has 24 burners with 12 burners on the front and rear walls. The burners are arranged in three rows of four burners on these walls. There are six pulverizers, with each feeding one row of four burners. This unit was originally designed with a pressurized furnace and was recently converted to balanced draft operation.

Crist Unit 7 has a rated capacity of 1.64 Gg steam per hour (3.6 x 10^6 lb/hr) of superheated steam at 17.2 MPa (2500 psia) and 810K (1000°F). Steam temperature is controlled by spray attemperation and flue gas proportioning dampers.

Flue gas cleaning equipment on Unit 7 consists of a cold side electrostatic precipitator (ESP). The flue gas exits the boiler in two ducts. There is a separate ESP for each duct. After leaving the ESP's, the ducts are combined and exit to the stack. Figure 2-1 shows a cross section of the boiler. The ESP arrangement is shown in Figure 2-2.

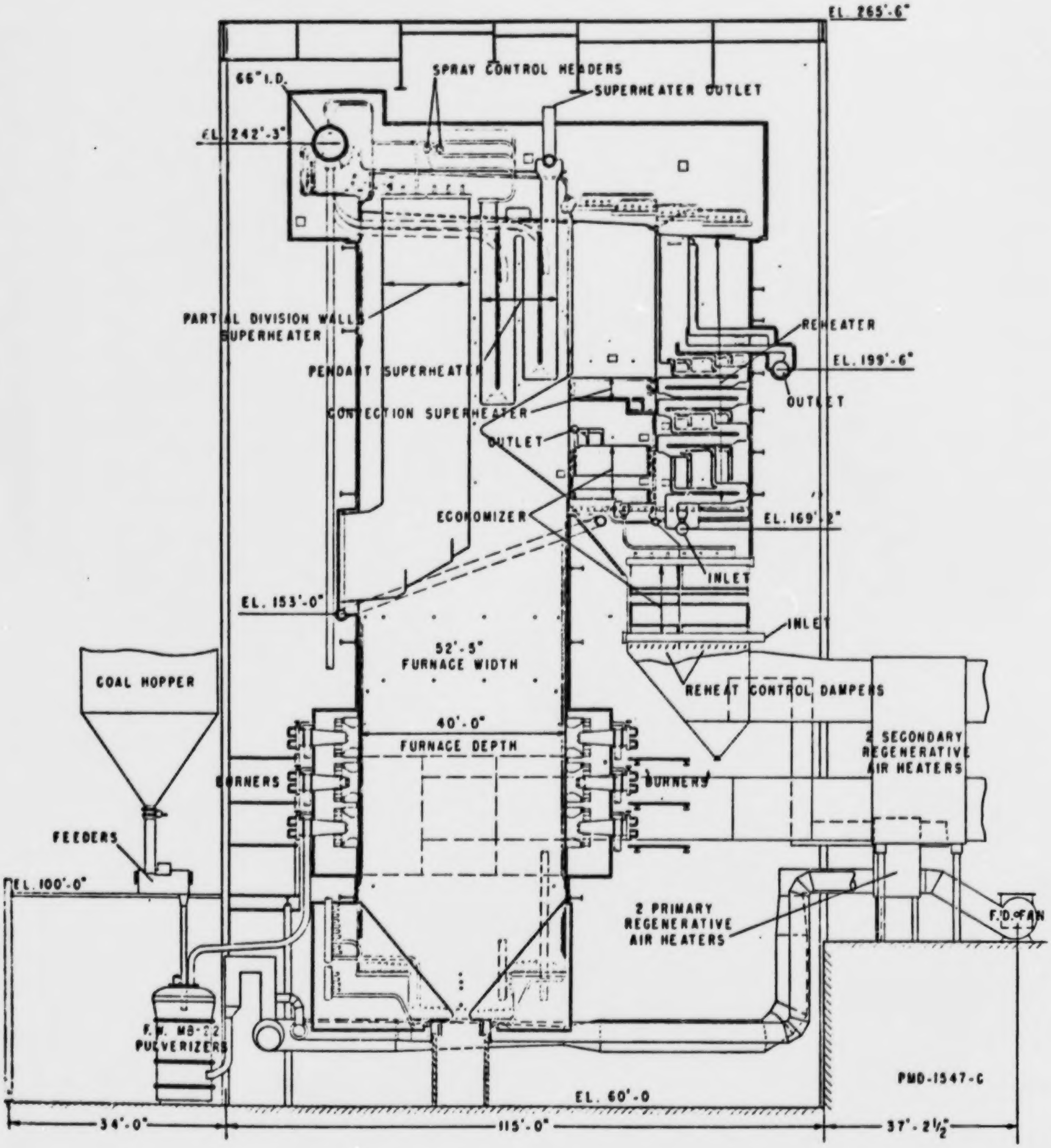

EL. 265'-6"
SPRAY CONTROL HEADERS
66" I.D.
SUPERHEATER OUTLET
EL. 242'-3"
PARTIAL DIVISION WALLS SUPERHEATER
PENDANT SUPERHEATER
REHEATER
EL. 199'-6"
CONVECTION SUPERHEATER
OUTLET
OUTLET
ECONOMIZER
EL. 169'-2"
INLET
EL. 153'-0"
INLET
52'-5" FURNACE WIDTH
COAL HOPPER
REHEAT CONTROL DAMPERS
40'-0" FURNACE DEPTH
2 SECONDARY REGENERATIVE AIR HEATERS
BURNERS
BURNERS
FEEDERS
EL. 100'-0"
2 PRIMARY REGENERATIVE AIR HEATERS
F.D. FAN
F.W. MB-22 PULVERIZERS
PMD-1547-C
EL. 60'-0
34'-0"
115'-0"
37'-2½"

Figure 2-1. Cross section of Crist, Unit 7 boiler.

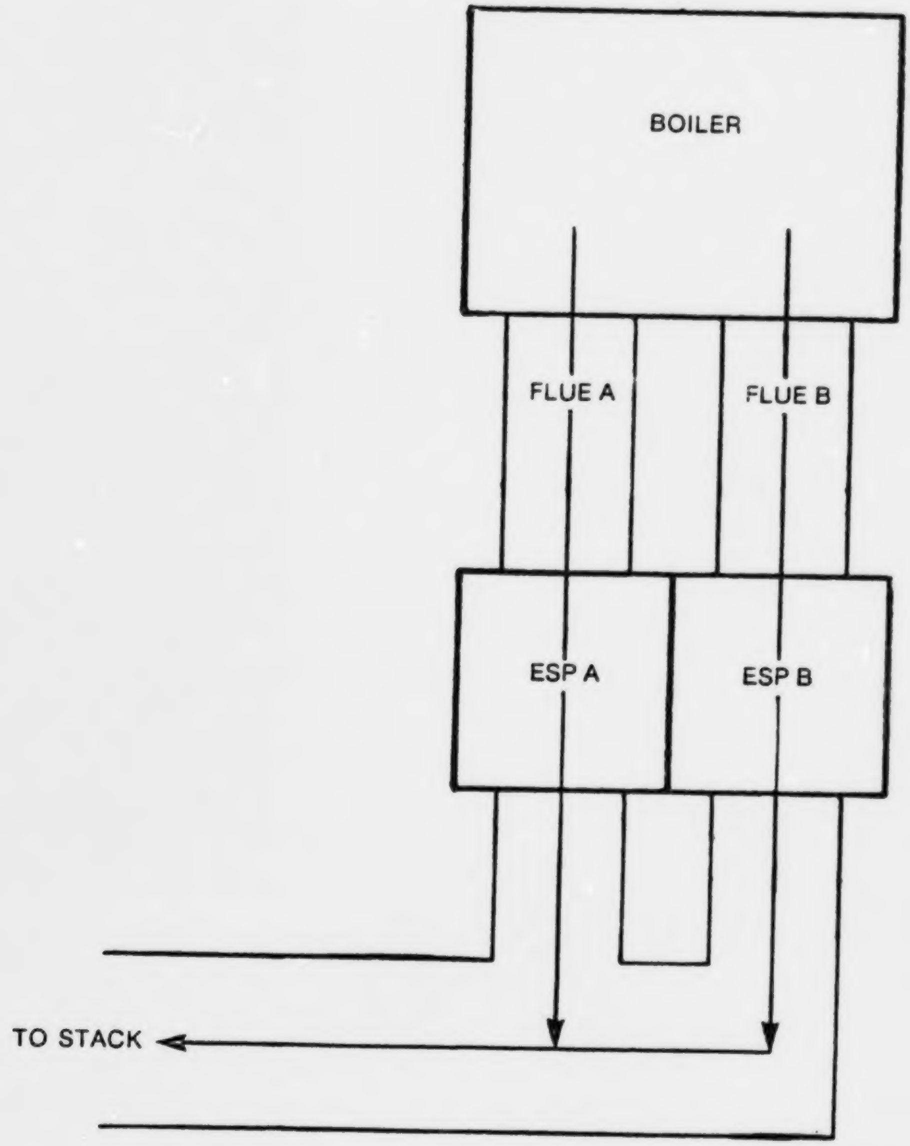

BOILER
FLUE A
FLUE B
ESP A
ESP B
TO STACK

Figure 2-2. ESP arrangement for Crist, Unit 7.

SECTION 3
TEST PLAN

The objective of this test program was to examine incremental changes in emissions and process operations as a result of combustion modification NO_x controls. In order to assess incremental changes, it was necessary to consider all influent and effluent streams. Process data were recorded periodically during each test so that changes in emissions could be related to process operation.

3.1 UNIT OPERATION

The test program at Crist examined incremental changes in emissions and operation at two levels of NO_x control. A baseline, "as found", test established the emission level uncontrolled for NO_x. For low NO_x burners-out-of-service (BOOS) operation, the top burner elevation on one wall admitted air only, while the lower elevations admitted fuel at greater than baseline rates. In the first test under low NO_x operation (BOOS 1), air only was admitted to the top row of burners on the front wall of the furnace. In the second test under controlled conditions (BOOS 2), air only was admitted to the top row of burners on the rear wall of the furnace.

Key operating parameters were held constant during the entire test program to simplify comparisons between tests. For all three firing conditions, the unit load was held constant at a generator output of approximately 440 MW. Other parameters held constant were steam temperature and steam pressure.

To the extent possible, other parameters of unit operation were held fixed during the three test conditions. Airflow, pulverizer feedrates, and air damper settings were not changed. Soot blowing cycles were completed prior to the start of each test and were not started again until the end of the test. Bottom ash was pulled prior to each test and again near the end of the test. This ensured the sampling of ash collected during the test period only.

The test program was performed as shown below:

- BOOS 1 -- June 21, 1978
- Baseline -- June 22, 1978
- BOOS 2 -- June 23, 1978

By scheduling a complete test each day of three consecutive days, the effects of coal supply variations were minimized and the risk of prolonging the test program due to forced equipment outages between test runs was reduced.

3.2 SAMPLING AND ANALYSIS

The sampling and analysis procedures used in this test program conform to a modified EPA Level 1 protocol. The purpose of these screening procedures is "to obtain preliminary environmental assessment information, identify problem areas, and provide the basis for the prioritization of streams, components, and classes of materials for further consideration in the overall assessment. As such, the results of the sampling and corresponding analysis procedures are quantitative within a factor of ± 2 to 3" (Reference 2).

The modifications to the specified Level 1 protocol used in these tests are listed below:

- Atomic absorption spectroscopy was used to assay for selected trace elements instead of spark source mass spectrometry
- Specific ion electrodes were used to assay for selected anions and ammonium ion instead of test kits
- Gas chromatography/mass spectrometry was used for identification and quantitation of polycyclic organic matter (POM) and priority pollutants instead of low resolution mass spectrometry

These modifications were used to improve the quantitative aspects of the analyses. The methods used for particulate, sulfur species, and the continuous monitors for NO_x, O_2, CO, and CO_2 were also more quantitative than the Level 1 screening procedures.

3.2.1 Sampling

In order to evaluate incremental changes in emissions, all influent and effluent streams must be analyzed. In this test program, all of these streams, with the exception of ambient air, were sampled and analyzed. The following samples were collected:

- Coal
- Bottom ash (slurry)
- Bottom ash sluice water
- ESP ash
- Flue gas
    - -- Continuous monitors for NO_x, CO, CO_2, O_2 upstream of air heater (continuous monitors operated by Exxon)
    - -- Source Assessment Sampling System (SASS) and combined EPA Method 5 (particulate) and EPA Method 8 (sulfur species) at the inlet to the ESP (SASS operated by Exxon; EPA Methods 5 and 8 operated by Entropy Environmentalists', Inc.)
    - -- SASS and combined EPA Method 5 and Method 8 at the outlet of the ESP (both trains operated by Acurex Corporaton)

A schematic showing sampling point locations is given in Figure 3-1. Descriptions of the sampling methods are given in the following paragraphs. Since each test required several hours to perform, the methods used allowed obtaining samples representative of the entire test.

3.2.1.1 Coal Samples

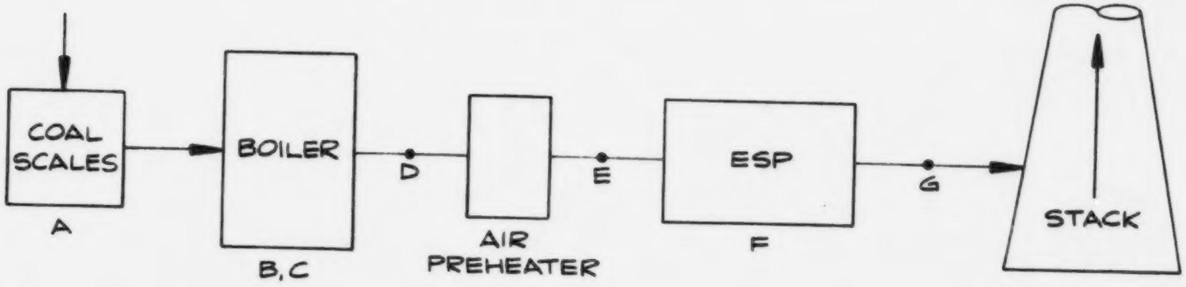
A grab sample from each coal feeder was collected at 30-minute intervals during the test. This composite sample was then ground and a representative sample extracted.

3.2.1.2 Bottom Ash

Immediately prior to the test, bottom ash was removed from the boiler. At the end of the test, bottom ash was removed again. This ensured that the bottom ash sample would come from the test period. The bottom ash was removed by a water sluice system. During the process, dipper sampling was used to obtain a composite bottom ash slurry sample. A sample of the sluice water inflow was also obtained for an analysis blank.

3.2.1.3 Flyash

Flyash collected by the electrostatic precipitator was sampled on 20-minute intervals during each test.


COAL SCALES
A
BOILER
B,C
D
AIR PREHEATER
E
ESP
F
G
STACK

Sampling Location	Type of Sample
A -- Coal Scales	Grab Sample -- Coal
B -- Sluice Water Inlet	Grab Sample -- Sluice Water Blank
C -- Bottom Ash Outlet	Grab Sample -- Bottom Ash Slurry
D -- Airheater Inlet	Gas Sample -- Continuous Monitors
E -- ESP Inlet	Gas Sample -- SASS, EPA 5/8
F -- ESP	Grab Sample -- ESP Ash
G -- ESP Outlet	Gas Sample -- SASS, EPA 5/8, Gas Grab Sample for GC analysis

Figure 3-1. Sampling locations.

3.2.1.4 Flue Gas Continuous Monitors

The continuous monitors for flue gas analysis were furnished by Exxon Research and Engineering in their mobile sampling van. The gas samples were taken from the ductwork between the boiler outlet and the air heater inlet (see Figure 3-2); and were taken continuously during each test. A description of the instrumentation in the Exxon sampling van is given in Table 3-1. Figure 3-3 presents a schematic of the flue gas continuous monitoring system.

3.2.1.5 Particulate and Sulfur Species

Combined EPA Methods 5 and 8 sampling trains using Acurex High Volume Stack Sampler (HVSS) systems were used to obtain particulate loading and sulfur species concentrations at the inlet and outlet of the electrostatic precipitator (see Figure 3-2). The sulfur species determined were gaseous SO_2 and SO_3 and particulate sulfate ($SO_4^=$).

As can be seen in Figure 3-2, EPA Methods 5 and 8 trains were located in three places. One train was located in each duct before the ESP inlet. One train was located downstream of the junction of the two ducts exiting the ESP. This arrangement allows sampling of the total gas stream entering and leaving the ESP.

3.2.1.6 Source Assessment Sampling System

Two Source Assessment Sampling System (SASS) trains were used simultaneously to sample the flue gas entering and leaving the electrostatic precipitator. These samples were used for trace element and organic species determinations in both vapor and condensed phases and also to provide particulate size distribution and trace element partitioning information.

The SASS train extracts the following samples:

- Particulate: >10 μm, 3 to 10 μm, 1 to 3 μm, 1 μm
- Vapor phase: XAD-2 porous polymer resin sorbent cartridge
  Aqueous condensate
  Hydrogen peroxide impinger
  Ammonium persulfate-silver nitrate impingers

A schematic of the SASS train is shown in Figure 3-4.

3.2.1.7 C_1 to C_6 Hydrocarbons

A gas grab sample was collected at the outlet of the ESP. The sample was collected in a Tedlar bag and then used to determine C_1 to C_6

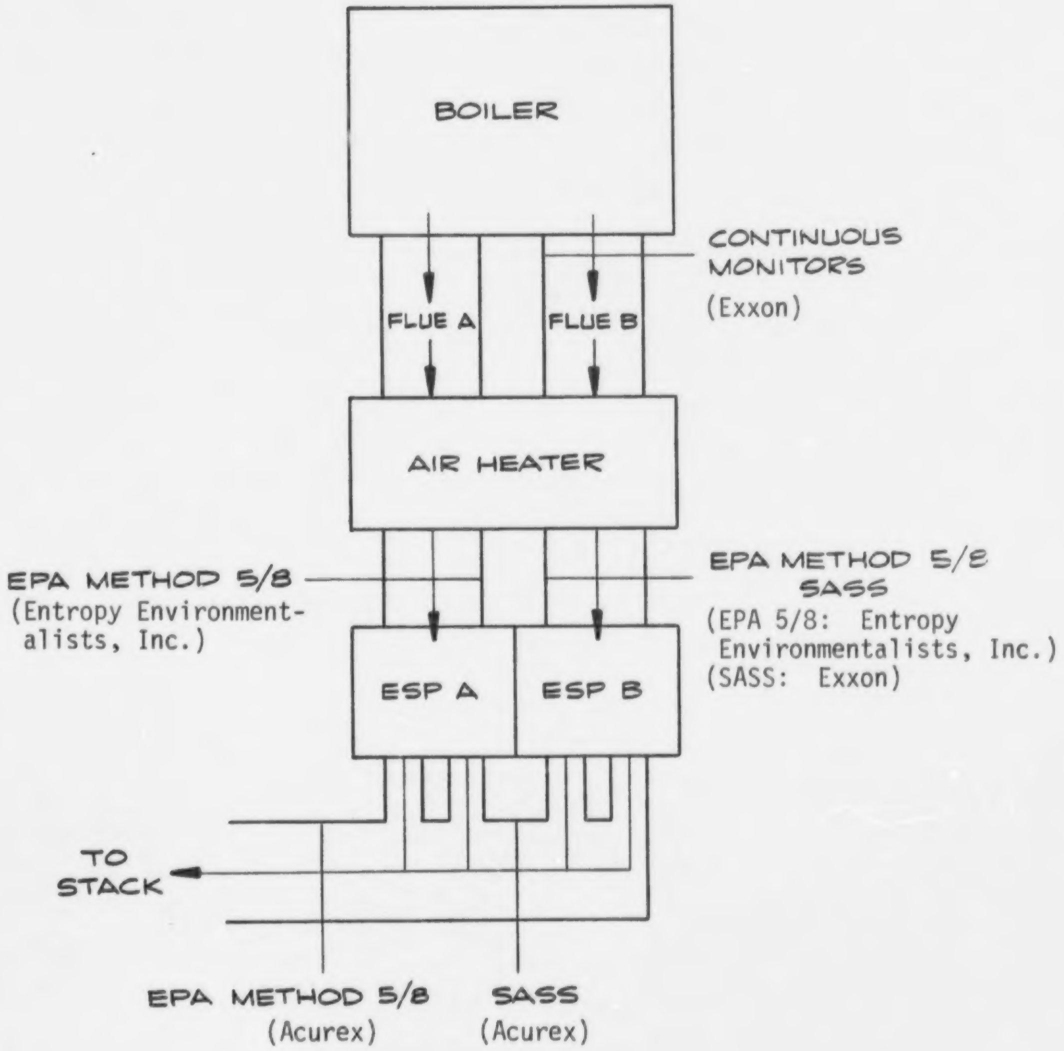

BOILER
FLUE A
FLUE B
CONTINUOUS MONITORS
(Exxon)
AIR HEATER
EPA METHOD 5/8
(Entropy Environmentalists, Inc.)
EPA METHOD 5/8
SASS
(EPA 5/8: Entropy Environmentalists, Inc.)
(SASS: Exxon)
ESP A
ESP B
TO STACK
EPA METHOD 5/8
(Acurex)
SASS
(Acurex)

Figure 3-2. Flue gas sampling locations.

TABLE 3-1. CONTINUOUS ANALYTICAL INSTRUMENTS IN EXXON VAN

Instruments	Technique	Measuring Range
Beckman		
NO	Non-dispersive Infrared	0 to 400 ppm 0 to 2000 ppm
NO_2	Non-dispersive Infrared	0 to 100 ppm 0 to 400 ppm
O_2	Polarographic	0 to 5 percent 0 to 25 percent
CO_2	Non-dispersive Infrared	0 to 20 percent
CO	Non-dispersive Infrared	0 to 200 ppm 0 to 1000 ppm 0 to 23,600 ppm
SO_2	Non-dispersive Infrared	0 to 600 ppm 0 to 3000 ppm
Hydrocarbons	Flame ionization detection	0 to 10 ppm 0 to 100 ppm 0 to 1000 ppm
Thermo Electron		
NO/NO_x	Chemiluminescent	0 to 2.5 ppm 0 to 10.0 ppm 0 to 25 ppm 0 to 100 ppm 0 to 250 ppm 0 to 1000 ppm 0 to 2500 ppm 0 to 10,000 ppm

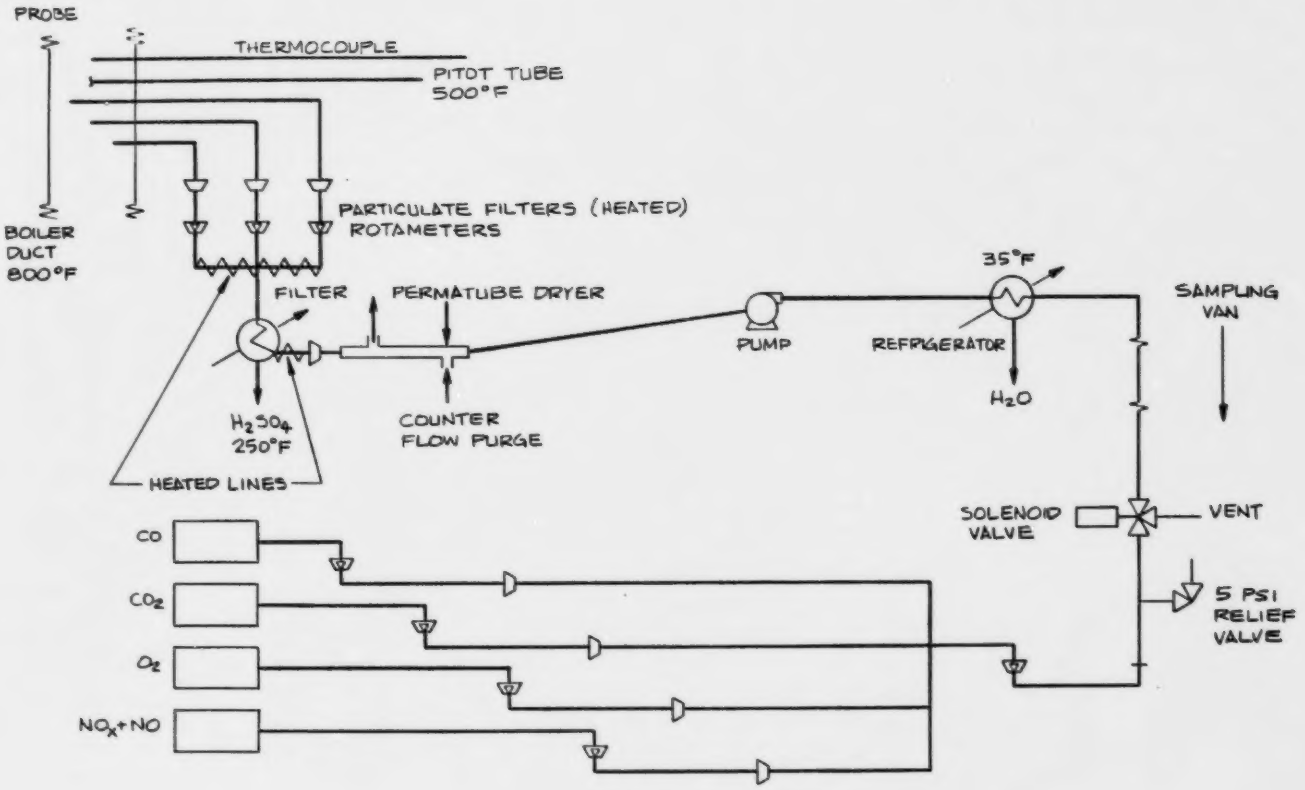

PROBE
THERMOCOUPLE
PITOT TUBE
500°F
BOILER
DUCT
800°F
PARTICULATE FILTERS (HEATED)
ROTAMETERS
FILTER
PERMATUBE DRYER
H_2SO_4
250°F
COUNTER
FLOW PURGE
HEATED LINES
PUMP
35°F
REFRIGERATOR
H_2O
SAMPLING
VAN
SOLENOID
VALVE
VENT
5 PSI
RELIEF
VALVE
CO
CO_2
O_2
NO_x+NO

Figure 3-3. Exxon Research transportable sampling and analytical system.

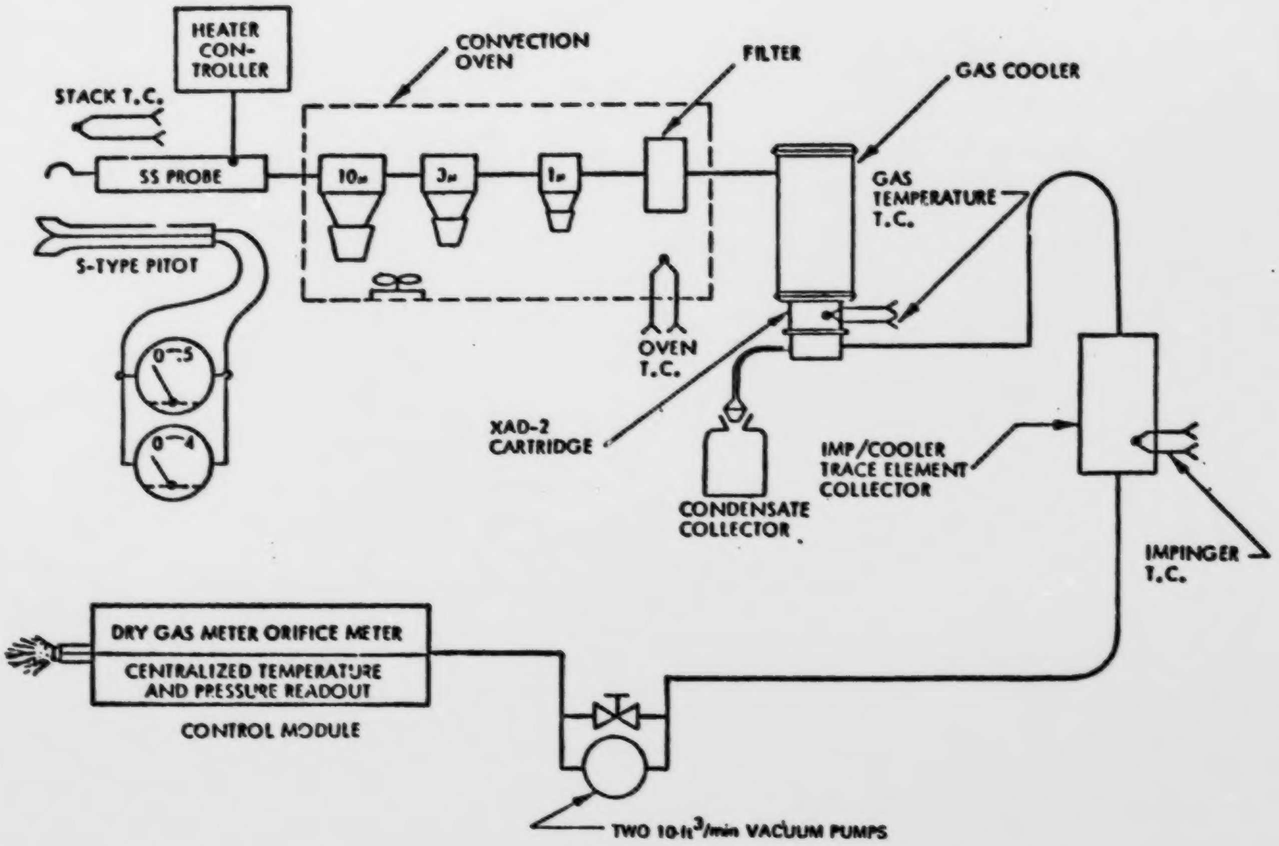

HEATER CON- TROLLER
STACK T.C.
SS PROBE
S-TYPE PITOT
0–.5
0–4
CONVECTION OVEN
10µ
3µ
1µ
FILTER
OVEN T.C.
XAD-2 CARTRIDGE
GAS COOLER
GAS TEMPERATURE T.C.
CONDENSATE COLLECTOR
IMP/COOLER TRACE ELEMENT COLLECTOR
IMPINGER T.C.
DRY GAS METER ORIFICE METER
CENTRALIZED TEMPERATURE AND PRESSURE READOUT
CONTROL MODULE
TWO 10-ft³/min VACUUM PUMPS

Figure 3-4. Source assessment sampling system (SASS) schematic (Reference 3).

hydrocarbon compounds by using an onsite gas chromatograph. A Carle Model 8500 portable gas chromatograph with flame ionization detector was used for this analysis.

3.2.2 Analysis

Table 3-2 lists the analyses performed on samples collected during each test. Descriptions of these analyses are given in the following paragraphs.

3.2.2.1 Operating Data Analysis

The key operating parameters listed in Table 3-3 were recorded hourly during each test. This unit operating data was used to calculate unit efficiency and to verify that unit operating parameters were being maintained according to the test plan. The average values for the operating parameters are given in Appendix A. Unit efficiency was calculated using the Heat Loss Method, ASME Abbreviated Efficiency Test (Reference 4). Results of these calculations are given in Appendix A.

3.2.2.2 Inorganic Analyses

Trace element analyses for the selected trace species in Table 3-4 were performed on fuel, bottom ash, ESP hopper ash, SASS flyash, and SASS impinger solutions. The procedure used for each trace element is outlined in Appendix B, "Elemental Analysis Flowsheet." Ash samples were also analyzed for selected anions: chloride, fluoride, nitrate, cyanide, and sulfate, plus ammonium as outlined in Appendix B. Proximate and ultimate analyses were conducted on the fuel samples. Flyash was assayed for unburned combustible material and major ash constituents as well as trace species.

3.2.2.3 Organic Analyses

Organic Analyses were performed in accordance with the EPA Level 1 protocol (References 2 and 5). The analyses included flue gas C_1 to C_6 hydrocarbons, organic material condensed on the ash samples, and organic material caught in the XAD-2 sorbent trap or retained in the condensate trap. The organic analysis techniques include Infrared Spectroscopy (IR), Low Resolution Mass Spectrometry (LRMS), and Gas Chromatography/Mass Spectrometry (GC/MS). GC/MS was used for polycyclic organic matter (POM) analysis (see Table 4-22). In addition to the above analyses, basic water analyses were performed on the bottom ash slurry

TABLE 3-2. SAMPLE ANALYSIS SCHEDULE

Fuel
    Proximate and Ultimate
    Trace Elements

Bottom Ash Sluice
Water Blank
    Trace Elements
    Water Analysis

Bottom Ash Slurry Filtrate
    Trace Elements
    Water Analysis

Bottom Ash Solids
    Trace Elements
    Organic Material
    Bioassay (BOOS 2 test only)

Bottom Ash Slurry
    Bioassay (BOOS 2 test only)

SASS Train ESP Inlet
    Trace Elements
    Organic Material

Methods 5 and 8 ESP Inlet

ESP Ash
    Trace Elements
    Organic Material
    Bioassay (BOOS 2 test only)

SASS Train ESP Outlet
    Trace Elements
    Organic Material
    Bioassay (BOOS 2 test only)

Methods 5 and 8 ESP Outlet

Flue Gas

NO_x, CO, CO_2, O_2, C_1 to C_6

TABLE 3-3. KEY OPERATING DATA COLLECTED AT CRIST, UNIT 7

- Steam
  - Outlet temperature
  - Outlet pressure
  - Reheat inlet pressure
  - Reheat inlet temperature
  - Reheat outlet pressure
  - Reheat outlet temperature
- Water
  - Feed flowrate
  - Feed temperature
  - Attemperation flow
  - Attemperation temperature
- Fuel
  - Flowrate
- Electrical Output

TABLE 3-4. TRACE SPECIES ANALYZED FOR IN CRIST SAMPLES

Antimony
Arsenic
Barium
Beryllium
Bismuth

Boron
Cadmium
Chromium
Cobalt
Copper

Iron
Lead
Manganese
Mercury
Molybdenum

Nickel
Selenium
Tellurium
Thallium
Tin

Titanium
Uranium
Vanadium
Zinc
Zirconium

Chloride
Fluoride
Cyanide
Nitrate
Sulfate
Ammonium

samples. An outline of the organic analyses procedures is given in Appendix B.

3.2.2.4 Bioassay Analyses

Bioassay analyses on selected samples were performed by Litton Bionetics and Union Carbide in accordance with EPA Level 1 protocol (Reference 6). Table 3-5 lists the samples for which bioassays were done and the bioassy protocol used.

TABLE 3-5. BIOASSAY ANALYSIS PROTOCOL

Sample	Bioassay Test
Outlet SASS Cyclones, 10 μm + 3 μm	Microbial Mutagenesis Cytotoxicity, RAM
Outlet SASS Cyclones, 1 μm + Filter	Microbial Mutagenesis Cytotoxicity, RAM
Bottom Ash Slurry	Freshwater Algal Bioassay Freshwater Static Bioassay
Bottom Ash Solids	Microbial Mutagenesis Cytotoxicity, RAM Rodent Acute Toxicity
ESP Hopper Ash	Microbial Mutagenesis Cytotoxicity, RAM Rodent Acute Toxicity Freshwater Algal Bioassay Freshwater Static Bioassay

SECTION 4
TEST PROGRAM RESULTS

Data from the test program provided information on unit operation, flue gas composition, particulate emissions, trace element emissions, sulfur species emissions, organic materials emissions, and water analyses. Data obtained are discussed in the sections that follow.

4.1 UNIT OPERATION

Unit operation was held essentially constant throughout each test. Key operating variables were controlled throughout the test program, so that tests could be compared to each other. A summary of the boiler operating conditions is given in Table 4-1. Detailed control room data are presented in Appendix A. The data in Appendix A and Table 4-1 are average values of the data recorded on hourly intervals during the test program.

Unit load and steam temperature and pressures were the key variables held constant during the test program. The unit load for the test program was held between 417 and 434 MW electrical generator output. Steam temperatures were maintained at 810 ± 3K (1000 ± 5^{o}F) at the superheater outlet and 810 ± 6K (1000 ± 10^{o}F) at the reheat outlet. Main steam flow was held between 1.61 and 1.69 Gg/h (3.54×10^{6} and 3.71×10^{6} lb/hr). Superheater outlet pressures varied from 13.3 to 14.0 MPa (1940 to 2030 psia) during the test program. Thus, all key parameters were maintained within 5 percent of each other during the program.

NO_x control consisted of varying the coal and air distribution so that the lower furnace was operating at a higher than Baseline fuel to air ratio. In the BOOS 2 test, the excess air level was also lower than the Baseline value. Excess air levels were 17 percent for the Baseline and BOOS 1 tests and 10 percent for the BOOS 2 test. Figure 4-1 shows burner arrangement, air register settings, and heat input for the three tests. Operating problems such as excessive slagging of the furnace or ash

TABLE 4-1. BOILER OPERATING CONDITIONS

Test	Generator Output MW	Coal Flow kg/s (ton/hr)	Heat Input[a] MW (10^6Btu/hr)	Flue Gas Flow[b] dscm/MJ (dscf/10^6 Btu)	Excess Air[c] Percent
Baseline	417	47.2 (187)	1,181 (4,030)	0.451 (16,780)	17
BOOS 1	431	46.3 (183)	1,210 (4,130)	0.502 (18,710)	17
BOOS 2	434	47.8 (189)	1,222 (4,169)	0.374 (13,930)	10

[a] Based on high heating value at constant volume
[b] At ESP outlet, EPA Method 5
[c] At boiler outlet, continuous monitors

BURNER ARRANGEMENT

	Front Wall 1	2	3	4
Row C	X	X	X	X
Row D	X	X	X	X
Row E	X	X	X	X

	Rear Wall 1	2	3	4
Row F	X	X	X	X
Row A	X	X	X	X
Row B	X	X	X	X

Air Register Settings (percent open)

Test	Baseline				BOOS (1 & 2)			
Burner	1	2	3	4	1	2	3	4
Row C	100	100	75	90	100	100	80	98
D	50	53	45	50	50	43	40	50
E	50	80	50	60	40	45	40	50
F	65	50	100	60	100	80	100	70
A	30	50	65	60	40	40	40	45
B	50	60	60	60	50	45	50	50

Heat Input MW, (10^6 Btu/hr)[a]

Test	Baseline	BOOS 1	BOOS 2
Row C	217 (741)	0	257 (877)
D	210 (718)	244 (833)	247 (845)
E	190 (647)	248 (847)	268 (914)
F	228 (777)	285 (973)	0
A	166 (567)	190 (649)	206 (705)
B	170 (580)	243 (828)	243 (828)
Total	1181 (4030)	1210 (4130)	1222 (4169)

---

[a] Based on high heating value at constant volume

Figure 4-1. Burner arrangement, air register settings, and heat input.

accumulation in the convective sections were not evident during the short duration of this test program. The effect of long term operation in the low NO_x mode is the subject of a study being conducted by Exxon Research and Engineering on this same unit.

Analysis results for the coal used during the test program are presented in Table 4-2. As shown in this table, the coals fired during the test program were very similar in composition. For example, nitrogen content varied from 1.12 to 1.14 percent. Sulfur varied from 3.39 to 3.89 percent.

Boiler efficiency for each of the tests was calculated using the ASME Abbreviated Efficiency Test, Heat Loss Method (Reference 4). The calculation results are given in Table 4-3; details are given in Appendix A. As shown in the table, the efficiencies were similar for the Baseline and BOOS 1 tests. In the BOOS 2 test, the efficiency improved slightly due to the reduced excess air levels. Changes in the unburned combustible material in the ash for the BOOS 2 test were more than offset by the reduced excess air level. Thus, the NO_x controls implemented did not impair boiler efficiency, and, when excess air levels were reduced, the boiler efficiency improved slightly.

4.2 FLUE GAS COMPOSITION

Table 4-4 lists the results obtained from continuous gas sampling at the boiler outlet. As expected, NO_x levels decreased for the BOOS firing mode. The decrease was 27 percent from Baseline for BOOS 1 firing, and 34 percent for BOOS 2 firing.

Flue gas composition did not change significantly with firing method except in CO concentration. The CO concentration in the flue gas for the BOOS 1 test was 608 ppm (3 percent O_2, dry) while CO concentrations for the other two tests were below 400 ppm. The raw data indicates fairly substantial oscillations in flue gas CO concentration for the BOOS 1 test. These swings in concentrations were not noted in the BOOS 2 or Baseline test. Also, there was a general trend to increasing CO concentration throughout the BOOS 1 test. Because the test was of short duration, no probable cause of this trend could be determined.

4.3 PARTICULATE EMISSIONS

Particulate emissions were measured in both ducts of the boiler outlet (ESP inlet) and both ducts of the ESP outlet. These measurements

TABLE 4-2. COAL AND ASH ANALYSES (PERCENT BY WEIGHT)

Coal Analysis	Baseline	BOOS 1	BOOS 2
Ultimate analysis (percent)			
Moisture	7.64	8.48	8.07
Ash	16.48	12.45	14.32
Carbon	59.62	62.18	61.61
Hydrogen	4.27	4.37	4.09
Nitrogen	1.12	1.14	1.12
Chlorine	0.05	0.08	0.05
Sulfur	3.70	3.89	3.39
Oxygen (diff.)	7.12	7.41	7.35
TOTAL	100.00	100.00	100.00
Proximate Analysis (percent)			
Moisture	7.64	8.48	8.07
Volatile Matter	33.00	34.47	33.43
Ash	16.48	12.45	14.32
Fixed Carbon	42.88	44.60	44.18
TOTAL	100.00	100.00	100.00
High Heating Value J/g (Btu/lb)	25,055 (10,782)	26,173 (11,263)	25,638 (11,033)
Ash Analysis (percent)			
SiO_2	45.63	40.25	44.93
Al_2O_3	21.21	18.38	21.05
TiO_2	0.90	0.81	0.89
Fe_3O_4	18.08	27.58	18.02
CaO	3.84	3.68	3.85
MgO	1.01	0.87	1.03
K_2O	2.67	2.35	2.65
Na_2O	0.31	0.48	0.32
SO_3	4.63	4.83	4.76
P_2O_5	0.27	0.19	0.28
SrO	0.00	0.00	0.00
BaO	0.07	0.03	0.07
Mn_3O_4	0.06	0.09	0.06
TOTAL	98.68	99.54	97.91

TABLE 4-3. BOILER EFFICIENCY

	Baseline	BOOS 1	BOOS 2
Heat Input (percent of Baseline)	100	102	103
Excess O_2 (percent of Baseline)	100	100	59
Efficiency (percent)	86.23	86.64	87.79
Heat loss due to combustibles in flyash (percent)	0.21	0.46	0.60
Heat loss due to dry flue gas (percent)	7.04	6.39	5.32

TABLE 4-4. FLUE GAS COMPOSITION

	Baseline	BOOS 1	BOOS 2
O_2 (percent dry)	3.2	3.3	2
CO_2 (percent dry)	13.4	13.3	16
CO (ppm @ 3% O_2 dry)	357	608	392
% Baseline	100	170	110
NO_x (ppm @ 3% O_2 dry)	725	488	510
% Baseline	100	67	70

were obtained by using EPA Method 5 and SASS techniques. EPA Method 5 employs multipoint equal area sampling to measure particulate concentrations. The SASS train provides particulate concentration data from a single point which corresponds to the point of average flue gas velocity. Simultaneous sampling at both the inlet and the outlet of the ESP will give the following information:

- Particulate concentration at the inlet and outlet of the ESP
- ESP collection efficiency
- Particle size distribution at the inlet and outlet of the ESP

These data will also show the effects of low NO_x firing on particulate concentration, size distribution, and collection efficiency.

Particulate concentration data from the EPA Method 5 and SASS sampling trains are presented in Table 4-5. Concentrations are reported on both a weight per volume of flue gas and heat input basis. The ESP inlet flue gas concentration for the Method 5 train is reported for both ducts. The SASS train operated in Duct B only.

EPA Method 5 results give inlet concentrations varying from an average of 8.66 g/m^3 to 9.12 g/m^3 and outlet concentration of 0.723 g/m^3 to 1.02 g/m^3. ESP efficiencies calculated from Method 5 results are approximately 90 percent for the three tests. SASS sampling results on the ESP inlet and outlet show the same trend as the EPA Method 5 results. A comparison between SASS and Method 5 data shows that, on the inlet, Method 5 results are consistently two to four times the SASS results. However, on the outlet, the SASS results were 2 to 3 times the Method 5 results. The SASS results, by virtue of the testing technique, are less accurate than the EPA Method 5 results. This is borne out by the results in Table 4-5.

Normalized particulate concentrations (g flyash/g ash in coal) are relatively constant for the BOOS 2 and Baseline tests. The normalized ash concentration for the BOOS 1 test is significantly higher than this quantity for the other two tests. This would indicate that more coal ash exited the boiler as flyash under BOOS 1 firing.

The collection efficiency of the ESP, by weight, can be calculated by comparing particulate loadings at the ESP inlet and outlet. Since EPA Method 5 techniques are assumed more accurate than SASS techniques at measuring particulate loading, the collection efficiency calculated by

TABLE 4-5. SASS AND EPA METHOD 5 PARTICULATE CONCENTRATION

	Baseline		BOOS 1		BOOS 2	
Duct	A	B	A	B	A	B
ESP Inlet Method 5 (SASS) (g/m^3)	8.58	8.73(1.98)	7.39[a]	10.2(2.68)	8.04	10.2(3.75)
Average (g/m^3)	8.66		8.77		9.12	
Heat input concentration Method 5 (SASS) (μg/J)	9.79 (1.1)		4.12 (1.26)		3.83 (1.57)	
ESP Outlet Method 5 (SASS) (g/m^3)	1.02 (2.60)		0.723 (2.02)		0.914 (2.33)	
Heat input concentration Method 5 (SASS) (μg/J)	0.46 (1.17)		0.36 (1.01)		0.34 (0.87)	
Inlet Concentration (g/g)[c]	0.73		0.87		0.69	
ESP collection efficiency (percent)[b]	95		91		91	

[a] Substantial leak detected in Method 5 train in duct A on this sheet
[b] Based on Method 5 heat input concentration
[c] Grams flyash/grams ash in coal

those results should be more accurate. Collection efficiencies calculated from Method 5 results indicate ESP collection efficiency of about 90 percent for all tests.

Particle size distributions at the ESP inlet and outlet are given in Tables 4-6 and 4-7. These data were obtained by using the weights of particulate collected in the SASS train cyclones. These cyclones have nominal cut sizes of 10, 3, and 1 μm. Actual cut sizes for the SASS cyclones have been determined to be 9.7, 3.7, and 1 μm (Reference 7). These cut sizes were used to determine particle size distribution and mean aerodynamic diameter.

Table 4-6 shows the particulate sizing at the ESP inlet. This table shows that the size distribution shifts to larger sizes from Baseline to BOOS 1 to BOOS 2. Table 4-7 shows the particle sizing at the ESP outlet. The results presented in this table show that the particle size distribution for the Baseline and BOOS 1 tests are approximately equal, but the BOOS 2 particle size distribution is shifted to smaller sizes.

The particle size distributions in Tables 4-6 and 4-7 were used to calculate the mean aerodynamic diameter (see Table 4-8). The results shown in Table 4-8 are inconsistent. This table shows that the mean aerodynamic size at the ESP outlet is greater than at the ESP inlet. These calculations are based on SASS train data. As mentioned in the discussion of Table 4-5, the SASS train data is inconsistent. From this analysis, the conclusion that the SASS trains did not get a representative sample can be drawn. Therefore, both SASS particulate loading and size distribution data are not representative of the duct conditions.

4.4 TRACE ELEMENT CHARACTERIZATION AND EMISSIONS

Samples taken at the various sampling locations shown in Figure 3-1 were analyzed for selected trace elements and ionic species. The samples collected and analyzed were:

- Coal
- Bottom ash slurry
- Sluice water inflow
- Flue gas SASS train samples at ESP inlet
- ESP hopper ash
- Flue gas SASS train samples at ESP outlet

TABLE 4-6. SASS TRAIN PARTICULATE SIZING (CUMULATIVE WEIGHT PERCENT OVERSIZE) ESP INLET

	Baseline	BOOS 1	BOOS 2
10 μm cyclone	33.6	36.8	48.2
3 μm cyclone	80.5	81.7	84.0
1 μm cyclone	95.4	96.1	97.1
Filter	100	100	100

TABLE 4-7. SASS TRAIN PARTICULATE SIZING (CUMULATIVE WEIGHT PERCENT OVERSIZE) ESP OUTLET

	Baseline	BOOS 1	BOOS 2
10 μm cyclone	57.0	60.0	50.3
3 μm cyclone	88.0	86.2	87.3
1 μm cyclone	98.8	98.0	96.1
Filter	100	100	100

TABLE 4-8. PARTICLE SIZE DISTRIBUTION (μm)

	Mean Diameter	20% Oversize	80% Oversize
Baseline			
ESP Inlet	6.9	14.5	3.3
ESP Outlet	11.5	25.0	5.4
BOOS 1			
ESP Inlet	7.5	15.7	3.6
ESP Outlet	13.0	32.0	5.4
BOOS 2			
ESP Inlet	9.5	21.2	4.2
ESP Outlet	10.1	25.0	4.3

The flue gas was sampled by using a SASS train. Grab samples were taken periodically from the other streams during the SASS test period. The results of the trace element analyses were presented in Appendix C.

Trace element concentrations reported for SASS train XAD-2 and impingers and the bottom ash have been corrected for blank concentrations. Bottom ash concentrations were also corrected for species detected in the sluice inflow water. All samples were combined with appropriate washes before analysis.

Once trace element concentrations were determined, trace element flowrates for each of the streams could be computed. Flyash flows were calculated from EPA Method 5 data. With this information, ESP hopper ash and bottom ash flows could be calculated. The trace element flowrates are presented in Appendix D.

In previous studies attempting to characterize trace element flows through coal-fired powerplants, trace element partitioning has been observed. Concentrations of some trace elements have been found to be higher in some streams than in others. This is due to a tendency for some trace elements to concentrate in particulates as a function of particle size. This separation between bottom ash and flyash is dependent on particle size and behavior at furnace temperatures. And, since collection efficiencies of various particulate removal devices are largely size dependent, size partitioning will influence relative trace element concentrations in hopper ash and flyash.

With respect to partitioning, the majority of trace elements (relevant to this study) have been put into one of three groups (Reference 8):

Group I -- Partitioned about equally between the inlet flyash and bottom ash
Group II -- Preferentially concentrated in the flyash
Group III -- Remain largely in the gas phase

A tabulation of the trace elements analyzed in these tests and their group assignment are given in Table 4-9.

4.4.1 Solid Phase Trace Element Concentrations

Trace element concentrations (Appendix C) in the bottom ash were compared to those in the ESP inlet ash to determine if solid phase trace element partitioning could be observed. As a result of this comparison, the trace elements were put into three groupings depending on whether: the material was partitioned about equally between bottom ash and flyash

TABLE 4-9. TRACE ELEMENT STREAM PARTITIONING[a]

Group I	Group II	Group III	Intermediate I-II
Barium	Antimony	Chlorine	Chromium
Cobalt	Arsenic	Fluorine	Nickel
Iron	Cadmium	Mercury	Uranium
Manganese	Copper	Thallium	Vanadium
Titanium	Lead		
	Molybdenum		
	Selenium		
	Zinc		

[a] The elements Beryllium, Bismuth, Boron, Tellurium, and Zirconium were not placed in a group.

(EQ); the material was preferentially concentrated in the flyash (FA) or; the material was preferentially concentrated in the bottom ash (BA).

The following criteria were used for categorization:

- If the concentration of a particular element did not differ by a factor of two or greater, when comparing flyash concentrations to bottom ash concentrations, the element partitioned equally (EQ)
- If the concentration of a given element in one stream was two or more times its concentration in the other stream, it was judged to partition in the former stream

As shown in Table 4-10, almost all of the trace elements were enhanced in the flyash. These partitioning tendencies are similar to what one would expect from the informaton in Table 4-9.

Low NO_x firing shows little effect on the trace element partitioning between bottom ash and flyash. Nickel became more concentrated in the flyash for low NO_x firing. Selenium and iron became less concentrated in the flyash in one of the low NO_x tests.

Further partitioning tendencies can be examined by comparing trace element concentrations in the particulate in the direction of flue gas flow. As the particulate laden flue gas passes through particulate removal devices, stream partitioning may be observed because particulate collection efficiencies are largely particle size dependent, with the coarser particles more easily removed.

Trace element concentrations in the ESP hopper ash and the ESP outlet flyash were compared (Appendix C). Using the same criterion as in the bottom ash/flyash comparison, trace element concentration data were evaluated for partitioning. Results of the comparison are shown in Table 4-11.

In the previous table, most trace elements were enhanced in the flyash. In this table, results show that most of the trace elements are enhanced in the ESP hopper ash. Also, more trace elements are partitioned equally than in the previous table. This is inconsistent with what would be expected. Since in Table 4-10, most trace elements were enhanced in the flyash, it would be expected that, in Table 4-11, trace elements would partition to outlet flyash rather than hopper ash. The results indicate the opposite is true, which would mean that the ESP preferentially captured small particles rather than larger ones. Again, this result is probably due to non-representative sample catches by the SASS train.

TABLE 4-10. SOLIDS TRACE ELEMENT PARTITIONING -- BOTTOM ASH/FLYASH

	Baseline	BOOS 1	BOOS 2
Barium	FA	FA	FA
Beryllium	FA	FA	FA
Bismuth	--	FA	--
Boron	--	FA	FA
Cadmium	--	FA	--
Chromium	FA	FA	FA
Cobalt	FA	--	FA
Copper	FA	FA	FA
Iron	FA	FA	EQ
Lead	FA	FA	FA
Manganese	FA	FA	FA
Nickel	EQ	FA	FA
Selenium	FA	EQ	FA
Tellurium	--	FA	--
Titanium	FA	FA	FA
Vanadium	FA	FA	FA
Zinc	FA	FA	FA

EQ = Material proportioned about equally between bottom ash and flyash
FA = Material preferentially concentrated in flyash
BA = Material preferentially concentrated in bottom ash
-- = Insufficient data

TABLE 4-11. TRACE ELEMENT PARTITIONING -- ESP HOPPER FLYASH/ESP OUTLET ASH

	Baseline	BOOS 1	BOOS 2
Arsenic	--	EQ	--
Barium	FA$_4$	FA$_3$	FA$_4$
Beryllium	EQ	EQ	FA$_3$
Bismuth	--	FA$_3$	--
Boron	FA$_3$	FA$_3$	FA$_3$
Cadmium	EQ	EQ	EQ
Chromium	FA$_3$	EQ	FA$_3$
Cobalt	--	FA$_3$	--
Copper	EQ	EQ	FA$_3$
Iron	FA$_3$	FA$_3$	FA$_3$
Lead	EQ	EQ	FA$_3$
Manganese	FA$_4$	FA$_3$	FA$_3$
Mercury	--	--	FA$_3$
Molybdenum	--	--	FA$_3$
Nickel	FA$_3$	EQ	FA$_3$
Selenium	FA$_3$	EQ	FA$_3$
Tin	FA$_3$	--	--
Titanium	FA$_3$	FA$_3$	FA$_3$
Vanadium	FA$_3$	FA$_3$	FA$_3$
Zinc	EQ	EQ	EQ
Chloride	EQ	EQ	--
Fluoride	FA$_3$	EQ	--
Cyanide	EQ	EQ	--
Nitrate	EQ	FA$_4$	--
Sulfate	EQ	EQ	--
Ammonium	FA$_4$	FA$_3$	--

EQ = Material proportioned about equally between ESP hopper ash and ESP outlet ash
FA$_3$ = Material preferentially concentrated in ESP hopper ash
FA$_4$ = Material preferentially concentrated in ESP outlet flyash
-- = Insufficient data

Of the species examined at the ESP outlet, six were found to partition equally in most of the tests. These were arsenic, beryllium, cadmium, copper, lead, and zinc. The only trace element concentrated in the ESP outlet flyash was barium. Manganese had a variable partitioning tendency. In the Baseline test, it was concentrated in the ESP outlet ash, but under low NO_x firing, it was concentrated in the ESP hopper ash. Low NO_x firing had no significant effect on the results other than for manganese.

4.4.2 Size Fractionation

Particle size information was obtained from SASS train sampling at the ESP inlet and outlet. For all tests, SASS trains were equipped with 10 μm, 3 μm, and 1 μm cyclones. Trace elements analyses were conducted on each of the cyclone catches. A tabulation of the analytical results are shown in Appendix C.

These data were examined to determine if selected trace element partitioning occurs with particle size. Concentration of the trace element in coarse particulate was defined to occur if the concentration of the trace element in the 10 μm cyclone catch was more than twice the concentration in the filter catch. Concentration in fine particulate was defined to occur if the concentration of the element in the filter catch was more than twice the concentration in the 10 μm cyclone catch. The results of this analysis are shown in Table 4-12.

Concentration enhancement in the fine particulate was seen in most of the tests for antimony, arsenic, cadmium, molybdenum, selenium, vanadium, and zinc, all Group II elements in Table 4-9. Concentration enhancement in coarse particulate was seen for barium, iron, and manganese, all Group I elements in Table 4-9. Thus these results agree with expected partitioning tendencies. This indicates that low NO_x firing modes had little effect on the tendency to partition with particle size.

4.4.3 Vapor Phase Trace Element Concentrations

Vapor phase trace element concentrations were obtained from the SASS train samples. The vapor phase species were collected in either the XAD-2 module or impinger portions of the SASS train. In the XAD-2 (organics) module, flue gas is cooled to approximately 293K (20°C) and passed through a cross linked porous polymer resin (XAD-2) cartridge.

TABLE 4-12. SIZE FRACTIONATION

Element	Baseline		BOOS 1		BOOS 2	
	ESP Inlet	ESP Outlet	ESP Inlet	ESP Outlet	ESP Inlet	ESP Outlet
Antimony	2	2	--	2	--	--
Arsenic	2	2	2	2	2	2
Barium	0	1	0	1	1	1
Beryllium	0	0	0	0	0	0
Bismuth	--	--	1	2	--	--
Cadmium	2	2	2	2	2	2
Chromium	0	0	0	0	0	2
Cobalt	0	1	0	2	0	0
Copper	0	0	2	1	0	0
Iron	1	0	1	1	1	0
Lead	0	0	1	0	0	2
Manganese	0	1	1	1	1	0
Mercury	--	--	0	0	--	0
Molybdenum	2	2	2	2	2	2
Nickel	0	0	0	0	1	0
Selenium	2	2	2	--	2	2
Tellurium	--	--	2	--	--	--
Thallium	--	--	--	--	--	--
Tin	--	2	--	--	--	--
Titanium	1	1	0	2	0	0
Vanadium	2	2	2	2	2	2
Zinc	0	0	2	2	2	2

0 = No size separation
1 = Concentration enhancement in the 10 μm fraction
2 = Concentration enhancement in the filter fraction
-- = Insufficient data

Condensible liquids are caught in a condensate trap. Thus, in this section, two samples are generated: the condensate and the XAD-2 sorbent. From the organics module, the flue gas goes through an impinger train with hydrogen peroxide and silver nitrate-ammonium persulfate solutions. In this analysis scheme, the condensate is extracted with methylene chloride yielding two fractions: an aqueous condensate and an organic condensate. For trace element analysis, the organic module aqueous condensate sample is combined with the hydrogen peroxide impinger sample for one analysis sample. The XAD-2 is analyzed for trace elements separately. Thus, three vapor phase samples are analyzed: the XAD-2 sorbent; the aqueous condensate plus the hydrogen peroxide impinger solution; and the silver nitrate -- ammonium persulfate impinger soultion.

To determine which trace elements were concentrated in the vapor phase, trace element flowrates (Appendix D) were compared. Trace elements were considered to be concentrated in the vapor phase if their vapor phase flowrates were at least twice their solid phase flowrate. Trace elements were considered to be concentrated in the condensed phase if their condensed phase flowrates were at least twice their vapor phase flowrate. The partitioning results are given in Table 4-13.

Vapor/solid partitioning is not strongly affected by firing method. Chromium, nickel, cobalt, selenium, and molybdenum showed high vapor phase concentrations. The chromium and nickel values are suspect, however. The aqueous condensate sample is collected in a stainless steel cup in the SASS train organics module. Since the condensate is acidic, chromium and nickel are likely to appear in the sample from the cup.

4.4.4 Elemental Mass Balance

System species mass balances around the boiler and around the boiler-ESP system were performed using trace element flow data (Appendix D). The results of these mass balances are presented in Tables 4-14 and 4-15.

The elemental balances on Table 4-14 show that the balances are about equally distributed around 100 percent. The balances in Table 4-15 are skewed less than 100 percent. This indicates that the ESP hopper ash or ESP outlet flows are low. However, considering these factors affecting the mass balance, the data are within the reliability of the Level 1

TABLE 4-13. TRACE ELEMENT PARTITIONING -- SOLID PHASE/VAPOR PHASE

	Baseline		BOOS 1		BOOS 2	
	ESP Inlet	ESP Outlet	ESP Inlet	ESP Outlet	ESP Inlet	ESP Outlet
Antimony	S	S	--	--	S	S
Arsenic	S	S	S	S	S	S
Barium	S	S	S	V	S	S
Beryllium	S	S	S	S	S	S
Bismuth	--	--	S	S	--	--
Boron	--	--	--	V	--	--
Cadmium	S	S	S	V	S	S
Chromium	EQ	V	S	V	S	V
Cobalt	S	V	S	V	S	V
Copper	S	S	S	S	S	S
Iron	S	S	S	S	S	S
Lead	S	S	S	S	EQ	S
Manganese	S	S	S	S	V	S
Mercury	--	--	--	V	--	V
Molybdenum	S	--	S	V	EQ	V
Nickel	V	V	S	V	S	V
Selenium	V	V	S	--	EQ	V
Tellurium	--	--	S	--	--	--
Tin	--	V	--	--	--	--
Titanium	S	S	S	S	S	S
Vanadium	S	S	S	S	S	S
Zinc	S	S	S	S	S	S

S = Concentrated in condensed phase
V = Concentrated in vapor phase
EQ = Equally partitioned between solid and vapor phase
-- = Insufficient data

TABLE 4-14. MASS BALANCE AROUND BOILER[a] OUTLET/INLET

Element	Baseline	BOOS 1	BOOS 2
Arsenic	5.24	11.4	6.15
Barium	2.51	1.98	2.77
Beryllium	1.39	1.49	1.26
Chromium	4.04	1.39	1.78
Cobalt	1.15	1.76	1.17
Copper	1.27	0.76	1.13
Iron	0.188	0.731	0.258
Lead	0.917	--	--
Manganese	1.91	1.55	2.48
Mercury	0.468	0.092	0.0
Molybdenum	0.890	0.198	0.509
Nickel	2.45	0.66	1.57
Selenium	0.703	0.088	0.872
Tin	0.095	--	--
Titanium	0.409	0.654	0.419
Vanadium	1.37	1.33	1.2
Zinc	1.84	1.08	1.96

[a] = Trace element concentration less than detection limit of analysis taken as zero.

-- = Insufficient data

TABLE 4-15. MASS BALANCE AROUND BOILER-ESP[a] OUTLET/INLET

Element	Baseline	BOOS 1	BOOS 2
Arsenic	0.327	2.49	0.508
Barium	0.667	2.29	0.454
Beryllium	0.962	0.895	0.849
Chromium	2.61	5.80	1.08
Cobalt	0.255	2.18	0.140
Copper	0.821	0.434	0.746
Iron	0.246	0.821	0.262
Lead	0.524	--	--
Manganese	2.52	1.98	2.03
Mercury	0.208	0.018	0.745
Molybdenum	0.325	0.055	0.320
Nickel	1.58	2.36	1.87
Selenium	0.779	0.776	0.885
Tin	0.191	--	0.001
Titanium	0.351	0.64	0.293
Vanadium	1.02	0.764	1.01
Zinc	0.735	0.681	0.623

[a] = Trace element concentration less than detection limit of analysis taken as zero.

-- = Insufficient data

sampling and analysis procedures, which are assumed to be quantitative within a factor of 2 to 3.

4.5 SULFUR SPECIES EMISSIONS

Sulfur species were analyzed in all sample streams according to the following protocol:

- Coal -- sulfur by ultimate analysis
- Bottom ash -- sulfate by titrametric method
- Flue gas at ESP inlet -- SO_2 and SO_3 by EPA Method 8 and sulfate on particulate by titrametric method
- ESP ash -- sulfate by titrametric method
- Flue gas at ESP outlet -- SO_2 and SO_3 by EPA Method 8 and sulfate on particulate by titrametric method

With this information, a sulfur species balance can be completed.

The results of the sulfur species analysis are presented in Table 4-16. The results of the sulfur species balance are presented in Table 4-17. The results in Table 4-16 show that the SO_2/SO_3 ratios are highest under low NO_x firing. The highest SO_2/SO_3 ratio is seen in the BOOS 1 test. This is because the ratio of SO_2 to all sulfur species ($SO_2 + SO_3 + SO_4$) increases with low NO_x firing, which is consistent with the greater reducing conditions in the boiler due to low NO_x firing.

The results of the sulfur species balances are presented in Table 4-17. With the exception of the Baseline sulfur balance at the ESP inlet, all balances closed within ±10 percent. Since the Baseline sulfur balance closed within ±10 percent on the ESP outlet, it seems that sulfur species concentrations and flowrates measured at the ESP inlet may be high by 10 to 20 percent.

4.6 ORGANIC ANALYSIS

Organic analyses were performed on selected samples according to the EPA Level 1 protocol as outlined in Appendix B (References 2 and 5). Table 4-18 shows the samples which underwent organic analyses.

The samples were analyzed as follows: First they were extracted with methylene chloride in a Soxhlet apparatus. The extracts were then subjected to total chromatographable organic (TCO) and gravimetric analyses which determine species with boiling points in the ranges of 373K to 573K ($100^{\circ}C$ to $300^{\circ}C$) and greater than 573K ($300^{\circ}C$), respectively.

TABLE 4-16. SULFUR SPECIES ANALYSIS

			Emissions		
Test	Location	Species	mg/m^3	ng/J	g/s
Baseline	ESP inlet	SO_2=			
		Duct A	6920	1930	2280
		Duct B	6280	1730	2050
		SO_3=			
		Duct A	7.63	2.12	2.51
		Duct B	3.33	0.918	1.09
		SO_4=			
		Duct A	--	--	--
		Duct B	--	--	--
	ESP outlet	SO_2=	6170	2780	3280
		SO_3=	21.1	9.48	11.2
		SO_4=	25.7	11.6	13.7
BOOS 1	ESP inlet	SO_2=			
		Duct A	7210	1650	2000
		Duct B	6580	1580	1910
		SO_3=			
		Duct A	5.01	1.15	1.39
		Duct B	2.72	0.651	0.789
		SO_4=			
		Duct A	--	--	--
		Duct B	--	--	--
	ESP outlet	SO_2=	6480	3250	3940
		SO_3=	7.22	3.62	4.39
		SO_4=	16.3	8.18	9.92

TABLE 4-16. Concluded

Test	Location	Species	Emissions		
			mg/m^3	ng/J	g/s
BOOS 2	ESP inlet	$SO_2^=$			
		Duct A	3420	692	846
		Duct B	8520	1850	2260
		$SO_3^=$			
		Duct A	2.38	0.481	0.588
		Duct B	2.45	0.532	0.651
		$SO_4^=$			
		Duct A	--	--	--
		Duct B	--	--	--
	ESP outlet	$SO_2^=$	7580	2830	3460
		$SO_3^=$	12.1	4.52	5.53
		$SO_4^=$	25.8	9.62	11.8

TABLE 4-17. SULFUR SPECIES BALANCE

	Baseline	BOOS 1	BOOS 2
Sulfur Input			
Fuel feedrate (kg/s)	47.2	46.3	47.7
Fuel sulfur content (%)	3.7	3.89	3.39
Sulfur input (kg/s)	1.75	1.80	1.62
Sulfur Output -- ESP Inlet			
Flue Gas			
$SO_2^=$(g/s)	4230	3910	3110
$SO_3^=$(g/s)	3.6	2.18	1.24
$SO_4^=$(g/s)	--	--	--
Total as sulfur (kg/s)	2.02	1.96	1.56
Bottom Ash			
SO_4 in slurry (mg/)	1.9	0	0.2
Sulfur in slurry (mg/)	0.6	0	0 7
S in slurry (kg/s)	1×10^{-5}	0	1.3×10^{-6}
Sulfur Recovery at ESP Inlet (%)	121	109	96
Sulfur Output -- ESP Outlet			
Flue Gas			
$SO_2^=$(g/s)	3280	3940	3460
$SO_3^=$(g/s)	11.2	4.39	5.53
$SO_4^=$(g/s)	13.7	9.92	11.8
Total as sulfur (kg/s)	1.65	1.98	1.74
Hopper Ash			
Sulfur in hopper ash (kg/s)	3.5×10^{-5}	3.8×10^{-5}	3.0×10^{-5}
Sulfur Recover at ESP Outlet (%)	94	110	107

TABLE 4-18. ORGANIC ANALYSIS SAMPLES FOR ALL TESTS

Bottom Ash

Bottom Ash Slurry

Flue Gas at ESP Inlet

- $10\,\mu m + 3\,\mu m$
- XAD-2

ESP Hopper Ash

Flue Gas at ESP Outlet

- $10\,\mu m + 3\,\mu m$
- XAD-2
- C_1 to C_6 hydrocarbons

Infrared spectra were also performed. If certain TCO and gravimetric requirements were met, further analyses by liquid column chromatography, with infrared and mass spectral analyses of the fractions eluted from the column, were performed. In addition, flue gas C_1 to C_6 hydrocarbon compounds were analyzed onsite by gas chromatography. Oxygen demand tests were performed (biological and chemical oxygen demand) on bottom ash sluice samples. A discussion of the analytical results follows.

4.6.1 C_1 to C_6 Flue Gas Hydrocarbon Analyses

Onsite analysis of C_1 to C_6 flue gas hydrocarbons were conducted during all three tests. The flue gas grab samples were analyzed by a gas chromatograph/flame ionization detector. The results are shown in Table 4-19.

As can be seen from Table 4-19, the BOOS 2 test has higher flue gas C_1 to C_6 hydrocarbon concentrations than the other two tests. The BOOS 2 test had a flue gas O_2 level of 2 percent as compared to about 3.2 percent for the other two tests. This indicates that excess air levels were low in the boiler, resulting in incomplete combustion. Increased hydrocarbon emissions were the result.

TABLE 4-19. FLUE GAS HYDROCARBON ANALYSIS

Test	Location	Component	Concentration (ppm @ 3% O_2)	Remarks
Baseline	ESP Inlet	Unknown	2.3	As CH_4
		Unknown	5.5	As CH_4
		Unknown	1.5	As CH_4
	ESP Outlet	Unknown	0.3	As CH_4
		Unknown	6.0	As CH_4
BOOS 1	ESP Inlet	Unknown	0.8	As CH_4
		Unknown	6.9	As CH_4
	ESP Outlet	Unknown	0.3	As CH_4
		Unknown	6.0	As CH_4
BOOS 2	ESP Inlet	Propane	2.3	
		Unknown	9.8	As CH_4
	ESP Outlet	Methane	1.3	
		Propane	1.7	
		Unknown	17.2	As CH_4

4.6.2 Total Chromatographable Organics (TCO) and Gravimetric Analyses of Organic Extracts

Total chromatographable organics (TCO) and gravimetric analyses were performed on organic extracts of the samples from the three tests. The samples analyzed were the bottom ash solids, electrostatic precipitator hopper ash, the 10 and 3 μm particulate samples collected by the SASS trains at both the inlet and outlet of the ESP, and the XAD-2 sorbent samples collected by the SASS train at the ESP inlet and outlet.

Detailed analytical results are presented in Table 4-20. Organic concentrations in all samples of ESP hopper ash were below detectable levels (<4.9 mg/kg). Bottom ash concentrations for the BOOS 1 and 2 tests were 12.1 and 16.6 mg/kg, respectively. However, for the Baseline test, bottom ash organic concentration was 124.8 mg/kg. No explanation for this discrepancy in bottom ash organic content is apparent. Organic analyses

TABLE 4-20. RESULTS OF TCO AND GRAVIMETRIC ANALYSES

Test	Sample	TCO Result (mg)	Gravimetric Result (mg)	Total Organics in Extract (mg)	Total
Baseline	Bottom ash	1.5	1.1	2.6	124.8 mg/kg
	ESP hopper ash	<0.1	<0.1	<0.1	<4.9 mg/kg
	XAD-2: ESP inlet	178.0	6.2	184.0	9.86 mg/m^3
	ESP outlet	82.1	32.9	115.0	4.32 mg/m^3
	Flyash: 10 μm + 3 μm				
	ESP inlet	0.9	<0.1	0.9	0.048 mg/m^3 87.8 mg/kg
	ESP outlet	<0.1	<0.1	<0.1	0.004 mg/m^3 9.8 mg/kg
BOOS 1	Bottom ash	<0.1	1.0	1.0	12.1 mg/kg
	ESP hopper ash	<0.1	<0.1	<0.1	<4.9 mg/kg
	XAD-2: ESP inlet	24.7	53.2	77.9	4.16 mg/m^3
	ESP outlet	15.4	<0.1	15.4	0.717 mg/m^3
	Flyash: 10 μm + 3 μm				
	ESP inlet	2.3	<0.1	2.3	0.123 mg/m^3 228.9 mg/kg
	ESP outlet	<0.1	<0.1	<0.1	0.005 mg/m^3 9.7 mg/kg
BOOS 2	Bottom ash	0.2	0.4	0.6	16.6 mg/kg
	ESP hopper ash	<0.1	<0.1	<0.1	4.9 mg/kg
	XAD-2: ESP inlet	22.7	32.2	54.9	2.43 mg/m^3
	ESP outlet	30.3	14.3	44.6	2.15 mg/m^3
	Flyash: 10 μm + 3 μm				
	ESP inlet	2.8	1.5	4.3	0.175 mg/m^3 416.3 mg/kg
	ESP outlet	<0.1	<0.1	<0.1	<0.004 mg/m^3 <9.9 mg/kg

of the SASS samples showed that there was little change in the vapor phase (XAD-2) organic concentrations in the flue gas due to low NO_x firing except that low NO_x conditions may have had slightly reduced organic emissions. Organic concentrations in the 10 and 3 μm cyclone catches also showed little change with firing mode.

4.6.3 Infrared and Gas Chromatographic/Mass Spectral Analysis of Total Extracts

The total sample extracts where analyzed by infrared spectroscopy (IR) and gas chromatography/mass spectrometry (GC/MS). A summary of the infrared spectroscopy results are shown in Table 4-21. The results show evidence of sample phthalate contamination. GC/MS analyses of the total samples for the compounds listed in Table 4-22 were also performed. This list includes polycyclic organic matter (POM) and priority pollutant species. The results of GC/MS analyses are shown in Tables 4-23, 4-24 and 4-25.

The major species seen in the GC/MS analysis are the POM species fluoranthene, fluorene, pyrene, and phenanthrene or anthracene, present at low levels, and phthalate contaminants. POM concentrations did not change significantly with firing method. The phthalates, especially bis (2-ethylhexyl) are present in samples at higher levels than seen in laboratory blanks. This is probably due to contamination.

4.6.4 Column Chromatography

The ESP inlet and outlet XAD-2 extract samples from the Baseline test were separated via liquid column chromatography. Gravimetric and TCO content were then obtained for each LC fraction. Results of these analyses are given in Tables 4-26 and 4-27.

4.6.5 Infrared and Mass Spectral (GC/MS and LRMS) Analyses of Fractions from Column Chromatography

The total samples obtained from column chromatography fractionation of the Baseline ESP inlet and outlet XAD-2 sample were split and analyzed by using Level 1 infrared and mass spectral techniques. Tables 4-28 and 4-29 summarize the infrared results for the baseline XAD-2 column chromatographic fractions.

Table 4-30 presents the results of GC/MS analysis of the XAD-2 combined fractions LC2 and LC3 from the ESP inlet and outlet. The results indicate that the same compounds were detected as in the total samples.

TABLE 4-21. IR ANALYSIS RESULTS SUMMARY

Test	Sample	Frequency, cm-1	Intensity	Possible Assignment
Baseline	Bottom Ash	3100-3600 1370 1250 1100 1010	S M M W W	Hydroxyl Alkane C-O Unassigned Unassigned
	Bottom Ash Slurry Filtrate	--	--	No peaks
	ESP Hopper Ash	--	--	All peaks in Blank
	Flyash: 10 μm + 3 μm:			
	ESP inlet	--	--	All peaks in Blank
	ESP outlet	3150-3600	S	Hydroxyl
	XAD-2			
	ESP inlet	1260	M	C-O
	ESP outlet	1260	S	C-O
BOOS 1	Bottom Ash	3100-3600	S	Aliphiatic C-H
	Bottom Ash Slurry Filtrate	--	--	No peaks
	ESP hopper Ash	--	--	All peaks in Blank
	Flyash: 10 μm + 3 μm			
	ESP inlet	2850, 2920, 2960	S	Aliphiatic C-H
	ESP outlet	3140-3600 1710	M M	Hydroxyl Unassigned

TABLE 4-21. Concluded

Test	Sample	Frequency, cm-1	Intensity	Possible Assignment
	XAD-2			
	ESP inlet	1000	M	Unassigned
	ESP outlet	1260	S	C-O
BOOS 2	Bottom ash	--	--	All peaks in Blank
	Bottom ash Slurry Filtrate	--	--	All peaks in Blank
	ESP Hopper Ash	1270	M	Unassigned
	Flyash: 10 μm + 3 μm			
	ESP inlet	1450 1260 1100 800	M S S S	Alkanes C-O Unassigned Ether
	ESP outlet	1730 1460	M M	C=O Alkanes

TABLE 4-22. COMPOUNDS FOR WHICH GC/MS ANALYSIS WAS PERFORMED

acenaphthene[a]
acenaphthalene[a]
anthanthrene[a]
anthracene[a]
benzidine[a]
benzo(a)anthracene[a]
3,4-benzofluoranthene[a]
benzo(k)fluoranthene[a]
benzo(g,h,i)perylene[a]
benzo(a)pyrene[a]
benzo(e)pyrene[a]
4-bromophenyl phenyl ether[a]
butyl benzyl phthalate[a]
bis(2-chloroethoxy) methane[a]
bis(2-chloroethyl)ether[a]
bis(2-chloroisopropyl) ether[a]
2-chloronaphthalenen
4-chlorophenyl phenyl ether[a]
chrysene[a]
dibenzo(a,h)anthracene[a]
dibenzo(c,g)carbazole[a]
dibenzo(a,h)pyrene[a]
dibenzo(a,i)pyrene[a]
di-n-butyl phthalate[a]
1,2 dichlorobenzene[a]
1,3 dichlorobenzene[a]
1,4 dichlorobenzene[a]
bis (2-ethylhexyl) phthalate[a]
3,3' dichlorobenzidine[a]
diethyl phthalate[a]
7,12 dimethyl benz(a) anthracene[a]
  dimethyl phthalate[a]
2,4-dinitrotoluene[a]
2,6-dinitrotoluene[a]
di-n-octyl phthalate[a]
1,2-diphenylhydrazine[a]
  (as azobenzene)
fluoranthene[a]
fluorene[a]
hexachlorobenzene[a]
hexachlorobutadiene[a]
hexachlorocyclopentadiene[a]
hexachloroethane[a]
indeno(1,2,3-c,d)pyrene[a]
isophorone
3-methyl cholanthrene[a]
naphthalene[a]
nitrobenzene[a]
N-nitrosodiphenylamine[a]
N-nitrosodi-n-propylamine[a]
perylene[a]
phenanthrene[a]
pyrene[a]
2,3,7,8-tetrachlorodibenzo-[a]
  p-dioxin
1,2,3-trichlorobenzene[a]

---

[a] Compound in calibration standard

TABLE 4-23. GC/MS RESULTS FOR TOTAL EXTRACTS -- BASELINE TEST

Compound	Bottom Ash (mg/kg)	Inlet XAD-2 ($\mu g/m^3$)	Outlet XAD-2 ($\mu g/m^3$)	Flyash: 10 μm + 3 μm ($\mu g/m^3$)
Bis (2-Ethylhexyl) phthalate	7.0	40.	4.	11.
Fluoranthene	--	0.2	0.1	--
Fluorene	--	0.1	--	--
Phenanthrene/ Anthracene	0.028	0.1	0.1	0.1
Pyrene	--	0.2	0.1	--
Silicones				92.0

TABLE 4-24 GC/MS RESULTS FOR TOTAL EXTRACTS -- BOOS 1 TEST[a]

Compound	Bottom Ash (mg/kg)	Outlet XAD-2 (μg/m^3)	Flyash: 10 μm + 3 μm (μg/m^3)
Bis (2-ethylhexyl) phthalate	0.03	50.	5.
Chrysene/benz (a) anthracene	--	0.1	--
Dichlorobenzene	--	0.2	--
Dimethyl phthalate	--	0.2	--
Fluoranthene	--	0.2	--
Fluorene	--	0.3	--
Naphthalene	--	--	0.3
Phenanthrene/anthracene	--	0.6	0.3
Pyrene	--	0.3	--
Silicones	--	0.3	70.

[a] Inlet XAD-2 sample was not analyzed

TABLE 4-25 GC/MS RESULTS FOR TOTAL EXTRACTS -- BOOS 2 TEST[a]

Compound	Inlet XAD-2 ($\mu g/m^3$)	Outlet XAD-2 ($\mu g/m^3$)	Flyash: 10 μm + 3um ($\mu g/m^3$)
Benzoic acid	50.	50.	--
Bis (2-ethylhexyl) phthalate	10.	50.	2.
Chrysene/benz (a) anthracene	0.1	--	--
Dichlorobenzene	0.2	0.2	--
Dimethyl phthalate	10.	50.	--
Fluoranthene	0.1	0.1	--
Naphthalene	0.6	0.5	0.4
Phenanthrene/ anthracene	0.5	0.8	0.2
Pyrene	0.2	0.3	--
Silicones	5.	5.	20.

[a] No compounds were found in bottom ash by GC/MS analysis

TABLE 4-26 GRAVIMETRIC AND TCO RESULTS OF COLUMN CHROMATOGRAPHY OF THE BASELINE ESP INLET XAD-2 SAMPLE

Fraction	TCO µg/m^3	Gravimetric µg/m^3	Total	
			µg/m^3	pg/J
LC 1	<0.5	561	562	310
LC 2	<0.5	5.37	5.9	3.26
LC 3	<0.5	268	269	148
LC 4	<0.5	50.1	50.6	28.0
LC 5	<0.5	24.2	24.7	13.7
LC 6	<0.5	434	435	240
LC 7	<0.5	166	167	92.2

TABLE 4-27. GRAVIMETRIC AND TCO RESULTS OF COLUMN CHROMATOGRAPHY OF THE BASELINE ESP OUTLET XAD-2 SAMPLE

Fraction	TCO µg/m^3	Gravimetric µg/m^3	Total	
			µg/m^3	pg/J
LC 1	< 0.4	470	470	260
LC 2	< 0.4	19.4	19.8	10.9
LC 3	< 0.4	48.4	48.8	27.
LC 4	< 0.4	46.5	46.9	25.9
LC 5	< 0.4	44.6	45.0	24.9
LC 6	< 0.4	466	466	258
LC 7	< 0.4	118	118	65.5

TABLE 4-28 INFRARED ANALYSIS OF COLUMN CHROMATOGRAPHICS OF THE BASELINE ESP INLET XAD-2 SAMPLE

Fraction	Frequency	Intensity	Possible Assignment
LC 1	--	--	All peaks in blank
LC 2	2920, 2840	S	Aliphatic C-H
LC 3	2960	S	Aliphatic C-H
LC 4	3350	W	-OH
	1750	M	C=O
	1650,1630,1580	M	Aromatic ring
	1460	M	CH_2, alkanes
	1250	M	C-O
	1100-1000	M	Unassigned
	800	M	Unassigned
	700	M	C-Cl
LC 5	--	--	No peaks
LC 6	3060	W	Aromatic C-H
	1600, 1550	M	Aromatic ring
	1270	M	C-O
	1060	M	Unassigned
	740, 710	W	Aromatic substitution, C-Cl
LC 7	--	--	No peaks

TABLE 4-29 INFRARED ANALYSIS OF COLUMN CHROMATOGRAPHICS OF BASELINE XAD-2 ESP OUTLET

Fraction	Frequency	Intensity	Possible Assignment
LC 1	1460	M	CH_2, alkanes
	1370	M	Alkanes
LC 2	2940,2920,2840	S	Aliphatic C-H
	1450	W	CH_2, alkanes
LC 3	--	--	No peaks
LC 4	3500-3100	W	-OH
	3080,3020	W	Aromatic C-H
	1720	M	C=O
	1650	W	Overtone
	1630	M	Aromatic ring
	1590	M	Aromatic ring
	1460	M	CH_2, Alkane
	1440	M	Alkane
	1260	M	C-O
	800	M	Unassigned
	690	M	Substitution, C-Cl
LC 5	2920,2840	S	Aliphatic C-H
LC 6	3080,3020	W	Aromatic C-H
	1600	W	Aromatic ring
	1550	W	Aromatic ring
	1100	M	C-O
	1065	M	Unassigned
	710	M	Unassigned, C-Cl
LC 7	3500-3100	W	-OH
	2920,2850	S	Aliphatic C-H
	1720	S	C=O

TABLE 4-30. GC/MS RESULTS OF LIQUID CHROMATOGRAPHIC FRACTIONS 2 + 3 OF THE BASELINE XAD-2 SAMPLE AT THE ESP INLET AND OUTLET

Compound	Inlet XAD-2($\mu g/m^3$) Fractions LC 2 + 3	Outlet XAD-2($\mu g/m^3$) Fractions LC 2 + 3
Bis (2-Ethylhexyl) Phthalate	--	0.8
Fluoranthene	0.4	0.1
Naphthalene	0.2	0.4
Phenanthrene/anthracene	0.5	0.5
Pyrene	0.5	0.2

Measured quantities in the sample fractions are a factor of two to five higher than those measured in the total sample. However, the quantities of POM detected in these experiments are close to the detection limit for the instrument and are, therefore, not highly accurate.

Low resolution mass spectrometry (LRMS) was done on the Baseline XAD-2 ESP inlet and outlet for fractions LC1, combined LC4 and LC5 and combined LC6 and LC7. In the ESP inlet LC1 fraction, a large amount of molecular sulfur was observed. No other species could be detected in any LRMS analysis.

4.6.6 Oxygen Demand

Chemical and biological oxygen demand analyses were performed on unfiltered bottom ash slurry samples. The results of these analyses are presented in Table 4-31. As shown in Table 4-31, there was no significant change in oxygen demand during the test program.

4.6.7 Summary of Organic Analyses

Comparison of the organic emissions of the three tests show that there was no significant change in organic emissions due to low NO_x firing. Flue gas hydrocarbon analysis showed that C_1 to C_6 hydrocarbon emissions did increase for the BOOS 2 test. This phenomenon is probably due to the lowered excess air levels used in this test.

Sample extracts were taken from bottom ash, ESP hopper ash, SASS train ESP inlet and outlet XAD-2, and SASS train ESP inlet and outlet combined 10 μm + 3 μm cyclone catches. These samples were subjected to TCO and gravimetric tests. The results of this test showed that the organic concentration in the Baseline bottom ash sample was higher than for BOOS 1 and BOOS 2. No explanation for this result could be determined. Infrared, and gas chromatography/mass spectrometry analyses were also conducted on the total sample extracts. No significant differences could be found between the result of the three tests.

4.7 BIOASSAY ANALYSES

Bioassay testing was conducted on samples collected during the BOOS 2 test. The samples tested were the bottom ash, the ESP hopper ash, and the particulate catch from the SASS train downstream of the ESP. The hopper ash and bottom ash samples were subjected to five different assays:

- Microbial Mutagenicity (Ames)
- Cytotoxicity using Rabbit Alveolar Macrophage (RAM)

TABLE 4-31. RESULTS OF BOD and COD ANALYSIS ON BOTTOM ASH SLURRY

Test	BOD, mg/l	COD, mg/l
Baseline	0.10	0[a]
BOOS 1	0[a]	24.9
BOOS 2	0.20	57.6

[a] Concentration in blank higher than concentration in sample

- Rat Acute (Oral) Toxicity
- Freshwater Algal Bioassay
- Freshwater Fish Acute Toxicity (Fathead Minnow)

The SASS train particulate loadings were combined into large (10 μm + 3 μm) and small (1 μm + filter) sized grouping. The Ames and RAM tests were conducted on both of these samples.

Bioassay results are shown in Table 4-32. This table shows that with one exception, all of the tests were either inconclusive or showed no detectable toxicity/mutagenicity within the test parameters. The RAM bioassay for the small particulate sample (1 μm + filter) from the SASS train yielded an EC50 value of 190 μg/ml, or a low toxicity level. Similar results were obtained from the electrostatic precipitator hopper ash RAM bioassay. For this sample, all of the assay parameters began to decrease at concentrations greater than 300 μg/ml, however, the EC50 value was still greater than 1000 μg/ml and thus judged to have non detectable toxicity.

Summaries of the bioassay test results are presented in Appendix E.

4.8 WATER ANALYSES

Water analyses were performed on filtered bottom ash slurry samples from the three tests. The results of the analyses are presented in Table 4-33.

In general, there is no significant change in the water analyses results between the three tests. However, conductivity and alkalinity showed the same trend. Both rose from Baseline to BOOS 1 to BOOS 2. These indicate increased ionic concentration in the bottom ash slurry due to low NO_x firing.

TABLE 4-32. CRIST BIOASSAY DATA

Sample	Salmonella Mutagenicity (Ames)	Rabbit Alveolar Macrophage (RAM)	Rat Oral Toxicity	Freshwater Algal Bioassay	Freshwater Fish Toxicity
Boiler Bottom Ash	ND	ND	ND	ND	ND
ESP Hopper Ash	ND	ND[a]	ND	ND	ND
SASS Train (10μm + 3μm particles)	ND	ND	--	--	--
SASS Train (1μm + Filter)	ND	L	--	--	--

ND No detectable results under the parameters of the experiment
L Low toxicity

[a] Although declared nondetectable, Litton Bionetics reported that all assay parameters (particularly ATP and ATP/10^6 cells) decreased relative to Re negative control for concentrations of test material greater than about 300 μg/ml

TABLE 4-33. WATER ANALYSIS RESULTS

	$SO_4^=$, mg/l	CN^-, mg/l	Alkalinity mg/l as $CaCO_3$	NO_3, mg/l	NO_2, mg/l	NH_3, mg/l	Conductivity, μ mho	Dissolved Solids, mg/l	Suspended Solids, mg/l
Baseline	0[a]	0[a]	4.6	0[a]	0[a]	0[a]	2.5	29	415
BOOS 1	1.9	0[a]	15.7	0[a]	0[a]	0.05	20	0[a]	494
BOOS 2	0.2	0.0002	29.6	0[a]	0[a]	0[a]	95	22	138

[a] Concentration in blank greater than concentration in sample

SECTION 5
SUMMARY

The test program conducted on Unit 7 of Gulf Power's Crist Power Plant compared changes in unit operation and multimedia emission resulting from NO_x control implementation. The results of a baseline or normal operation, test were compared to test results from two modes of low NO_x operation. Both NO_x control techniques consisted of burners-out-of-service (BOOS). Also, the second BOOS test was conducted at lower than baseline excess air levels. NO_x reduction from baseline level of 27 to 34 percent were observed, respectively. Summaries of the effects on boiler operations and emissions are given below.

5.1 OPERATION

The combustion modification NO_x controls employed in this test program did not appear to cause any operating problems during the test program. Steam temperatures were maintained at 810 ± 3K (1000°F). No excessive slagging of the furnace was noted.

The combustion modifications consisted of varying the coal and air distribution so that the lower furnace was operating at a higher than baseline fuel-to-air ratio. This was done by admitting no fuel to the top row of burners on one furnace wall. In the BOOS 1 test, fuel was shut off to the top row of burners on the front wall of the furnace. In the BOOS 2 test, fuel flow was restored to the top row on the front wall and stopped to the top row on the rear wall. Also, the excess air level in the BOOS 2 test was reduced below baseline level. In both tests, fuel flow was increased to the burners remaining in service.

Low NO_x operation of the boiler did not require reduction of boiler load. Boiler output was maintained between 417 and 434 MW throughout the tests. Boiler efficiency was not affected by firing mode except for a slight increase in the BOOS 2 test. This result was due to lowered excess air levels.

5.2 EMISSIONS

Multimedia emissions were examined for changes due to NO_x controls. Gaseous, particulate, trace element, sulfur species, and organic emissions were evaluated. The test program results are discussed briefly in the following paragraphs.

Gaseous NO_x, CO, O_2 and CO_2 were measured by continuous monitors throughout the test. NO_x control measures reduced NO_x emissions by 27 percent for the BOOS 1 test and 34 percent for the BOOS 2 test. CO concentration increased slightly under low NO_x firing.

Particulate testing showed that particulate emissions were not greatly affected by firing mode. Also, particle size distribution and ESP collection efficiency did not vary significantly with firing mode.

Trace element results showed that trace species partitioning generally followed the results in other tests and that, in general, changes in partitioning were within the accuracy of the analyses. Also, reduced nitrogen compound concentrations did not increase with low NO_x firing.

The results of the sulfur species analysis showed that flue gas SO_2 levels varied with fuel sulfur and not with firing mode. Also, the percent of fuel sulfur oxidized to SO_3 and SO_4 decreased because of reducing conditions in the boiler due to NO_x controls.

Organic emissions from the three tests were compared. The results showed that there is no significant change in organic emissions due to low NO_x firing. Flue gas C_1 to C_6 hydrocarbon emissions were increased in the BOOS 2 test due to lowered excess air. Infrared (IR) and gas chromatographic/mass spectrometric (GC/MS) analyses were performed on total sample extracts from all three tests. No significant difference in species or quantity found was seen between samples from the three tests.

Bioassays were performed on selected samples from the BOOS 2 test. All samples had nondetectable toxicity in all bioassays except the combined 1 μm and filter sample from the ESP outlet. This sample was found to have low toxicity in the Rabbit Alveolar Macrophage test.

REFERENCES

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4. "Performance Test Code Steam Generating Units," PTC 4.1, American Society of Mechanical Engineers, 1965.

5. "IERL-RTP Analysis Manual for Level 1 Environmental Assessment," ADL-783467-10-2, February 1977.

6. Duke, K. M., et al., "IERL-RTP Procedures Manual: Level 1 Environmental Assessment Biological Tests for Pilot Studies," EPA-600/7-77-043, April 1977.

7. Blake, D. E., "Source Assessment Sampling System: Design and Development," EPA-600/7-78-018, January 1977.

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APPENDIX A

OPERATING DATA AND EFFICIENCY TEST RESULTS

ITEM	UNITS	BOOS 1 6/21/78	BASELINE 6/22/78	BOOS 2 6/23/78
COLD REHEAT	PSIG	538	533	545
HOT REHEAT	PSIG	515	520	525
COLD REHEAT	^{o}F	647	639	652
PRIM. AIR OUT "A"	^{o}F	351	231	440
PRIM. GAS OUT "A"	^{o}F	215	169	256
PRIM. AIR OUT "B"	^{o}F	386	243	434
PRIM. GAS OUT "B"	^{o}F	239	173	264
SEC. AIR IN "A"	^{o}F	115	119	121
FROM PREHEATER GAS OUT "A"	^{o}F	338	324	323
SEC.AIR IN "B"	^{o}F	114	119	120
FROM PREHEATER GAS OUT "B"	^{o}F	344	406	357
FD "A" DISC. PRES.	IN H_2O	10	14	9
FD "B" DISC. PRES.	IN H_2O	14	16	11
SEC. AIR HTR. 7A GAS DIF.	IN H_2O	5.3	7.8	4.9
SEC. AIR HTR. 7B GAS DIF.	IN H_2O	5.0	7.0	4.4
FURN. GAS. PRES.	IN H_2O	- 0.9	- 0.9	- 0.9
ECONO. INLET GAS PRES.	IN H_2O	3.6	- 5.0	- 3.2

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ITEM	UNITS	BOOS 1 6/21/78	BASELINE 6/22/78	BOOS 2 6/23/78
PULV. A COAL FEED	1,000 lb/hr	51	47	57
PULV. B COAL FEED	1,000 lb/hr	77	57	78
PULV. C.COAL FEED	1,000 lb/hr	0	72	83.5
PULV. D.COAL FEED	1,000 lb/hr	77	70	80
PULV. E.COAL FEED	1,000 lb/hr	73	59	80
PULV. F.COAL FEED	1,000 lb/hr	87	72	0
GROSS LOAD	MW	431	417	434
THROTTLE PRES.	PSIG	1924	2020	1920
S.H. OUT STEAM	° F	995	1005	1003
R.H. OUT STEAM	° F	990	1004	1003
SEC AIR OUT "A"	° F	634	625	624
SEC AIR OUT "B"	° F	601	656	621
ECONO GAS OUT B	° F	733	759	742
ECONO GAS OUT A	° F	742	769	731
AVE. PULV. TEMP.	° F	132	131	145
% O_2 "B"	%	1.75	4.58	1.29
% O_2 "A"	%	2.29	4.15	2.03

ITEM	UNITS	BOOS 1 6/21/78	BASELINE 6/22/78	BOOS 2 6/23/78
MAIN STEAM FLOW	1,000 lb/hr	3643	3538	3710
FEED WATER FLOW	1,000 lb/hr	2908	2715	2860
CONDENSATE FLOW	1,000 lb/hr	2937	2825	2930
AIR FLOW	1,000 lb/hr	2212	2262	2200
PLUME OPACITY	%	35	-	-
VACUUM	IN Hg.	26.5	26.0	26.5
BFP 7A FLOW	1,000 lb/hr	1663	1570	1680
BFP 7B FLOW	1,000 lb/hr	1653	1567	1610
1D DUCT SUCTION	IN Hg.	-16	-21.5	-15
ECONO OUTLET	IN Hg.	- 5	- 7.0	- 4.9
1D FAN SUCTION A	IN Hg.	-14	-19	-13
1D FAN SUCTION B	IN Hg.	-14	-19	-13
1D FAN SUCTION C	IN Hg.	-14	-19	-13
1D FAN SUCTION D	IN Hg.	-14	-19	-13
1D FAN CUR. A	Amps	413	532	400
1D FAN CUR. B	Amps	460	547	410
1D FAN CUR. C	Amps	462	547	430

ITEM	UNITS	BOOS 1 6/21/78	BASELINE 6/22/78	BOOS 2 6/23/78
1D FAN CUR. D	Amps	0	0	0
COAL SCALE A	1,000 lb/hr	57.65	52.61	63.94
COAL SCALE B	1,000 lb/hr	73.49	53.76	75.01
COAL SCALE C	1,000 lb/hr	0	68.77	79.50
COAL SCALE D	1,000 lb/hr	73.94	66.59	76.61
COAL SCALE E	1,000 lb/hr	75.22	60.00	82.85
COAL SCALE F	1,000 lb/hr	86.35	72.04	0
PULV CUR. A	Amps	62	61	64
PULV CUR. B	Amps	56.5	52	59
PULV CUR. C	Amps	0	57	62
PULV CUR. D	Amps	58	55	60
PULV CUR E	Amps	61	58	68
PULV CUR. F	Amps	54	50	0
SPRAY VALVE S.H. LOW 7A	%	29	32	34
SPRAY VALVE S.H. LOW 7B	%	41	42	52
SPRAY VALVE S.H. UP. 7A	%	28	47	26
SPRAY VALVE S.H. UP. 7B	%	28	47	26

ITEM	UNITS	BOOS 1 6/21/78	BASELINE 6/22/78	BOOS 2 6/23/78
SPRAY VALVE RH	%	0	0	0
FEED WATER TEMP	°F	430	430	430
#7 HTR INLET	°F	647	639	653
#7 HTR. PRES	PSIG	553	527	555
ECONO INLET	°F	483	480	480
#7 HTR DRAIN	°F	461	455	462
FD FAN CUR. 7A	Amps	410	463	400
FD FAN CUR 7B	Amps	430	432	400
WET BULB	°F	77	77	79
DRY BULB	°F	91	92	94
HUMIDITY	%	54	51	52
HUMIDITY	$\frac{\text{lb } H_2O}{\text{lb AIR}}$	0.0169	0.0166	0.0180

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

ER OF PLANT Crist	TEST NO. BASELINE	BOILER NO.	DATE 6-20-78
CONDUCTED BY	LOCATION	
BOILER, MAKE & TYPE	OBJECTIVE OF TEST	DURATION
STOKER, TYPE & SIZE		RATED CAPACITY
PULVERIZER, TYPE & SIZE		
FUEL USED	MINE	BURNER, TYPE & SIZE
	COUNTY	STATE	SIZE AS FIRED

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	
2	STEAM PRESSURE AT S. H. OUTLET	psia	
3	STEAM PRESSURE AT R. H. INLET	psia	
4	STEAM PRESSURE AT R. H. OUTLET	psia	
5	STEAM TEMPERATURE AT S. H. OUTLET	F	
6	STEAM TEMPERATURE AT R.H. INLET	F	
7	STEAM TEMPERATURE AT R.H. OUTLET	F	
8	WATER TEMP. ENTERING (ECON.)(BOILER)	F	
9	STEAM QUALITY % MOISTURE OR P. P. M.		
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	
11	TEMP. AIR FOR COMBUSTION (This is Reference Temperature) †	F	
12	TEMPERATURE OF FUEL	F	
13	GAS TEMP. LEAVING (Boiler) (Econ.) (Air Htr.)	F	
	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	
16	ENTHALPY OF (SATURATED) (SUPERHEATED) STM.	Btu/lb	
17	ENTHALPY OF SAT. FEED TO (BOILER) (ECON.)	Btu/lb	
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	135.1
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	.5947
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	11.6

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	
27	REHEAT STEAM FLOW	lb/hr	
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	
29	TOTAL HEAT INPUT $\frac{\text{Item 28} \times \text{Item 41}}{1000}$	kB/hr	
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	
31	TOTAL HEAT OUTPUT $\frac{(\text{Item 26} \times \text{Item 20}) + (\text{Item 27} \times \text{Item 21})}{1000}$ + Item 30	kB/hr	

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	13.4
33	O_2	% VOL	3.2
34	CO	% VOL	
35	N_2 (BY DIFFERENCE)	% VOL	83.4
36	EXCESS AIR	%	17

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	7.64	51	FLASH POINT F*	
38	VOL MATTER	33.0	52	Sp. Gravity Deg. API*	
39	FIXED CARBON	42.88	53	VISCOSITY AT SSU* BURNER SSF	
40	ASH	16.48	44	TOTAL HYDROGEN % wt	
	TOTAL	100.00	41	Btu per lb	
41	Btu per lb AS FIRED	10782 @ C.V. 10793 @ C.P.			
42	ASH SOFT TEMP.* ASTM METHOD			GAS	% VOL

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS				
			54	CO	
43	CARBON	59.62	55	CH_4 METHANE	
44	HYDROGEN	4.27	56	C_2H_2 ACETYLENE	
45	OXYGEN	7.12	57	C_2H_4 ETHYLENE	
46	NITROGEN	1.12	58	C_2H_6 ETHANE	
47	SULPHUR	3.70	59	H_2S	
40	ASH	16.48	60	CO_2	
37	MOISTURE	7.69	61	H_2 HYDROGEN	
	TOTAL	100.00		TOTAL	

	COAL PULVERIZATION				
				TOTAL HYDROGEN % wt	
48	GRINDABILITY INDEX*		62	DENSITY 68 F ATM. PRESS.	
49	FINENESS % THRU 50 M*		63	Btu PER CU FT	
50	FINENESS % THRU 200 M*		41	Btu PER LB	
64	INPUT-OUTPUT EFFICIENCY OF UNIT %	$\frac{\text{ITEM 31} \times 100}{\text{ITEM 29}}$			

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	760	7.04
66	HEAT LOSS DUE TO MOISTURE IN FUEL	87	.81
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	436	4.0
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	22.3	.21
69	HEAT LOSS DUE TO RADIATION		.21
70	UNMEASURED LOSSES		1.5
71	TOTAL		13.77
72	EFFICIENCY = (100 – Item 71)		86.23

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

ER OF PLANT Crist
TEST NO. Boos 1
BOILER NO.
DATE 6-21-78
LOCATION
CONDUCTED BY
OBJECTIVE OF TEST
DURATION
BOILER, MAKE & TYPE
RATED CAPACITY
STOKER, TYPE & SIZE
PULVERIZER, TYPE & SIZE
BURNER, TYPE & SIZE
FUEL USED
MINE
COUNTY
STATE
SIZE AS FIRED

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	
2	STEAM PRESSURE AT S. H. OUTLET	psia	
3	STEAM PRESSURE AT R. H. INLET	psia	
4	STEAM PRESSURE AT R. H. OUTLET	psia	
5	STEAM TEMPERATURE AT S. H. OUTLET	F	
6	STEAM TEMPERATURE AT R.H. INLET	F	
7	STEAM TEMPERATURE AT R.H. OUTLET	F	
8	WATER TEMP. ENTERING (ECON.) (BOILER)	F	
9	STEAM QUALITY % MOISTURE OR P. P. M.		
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	
11	TEMP. AIR FOR COMBUSTION (This is Reference Temperature) †	F	
12	TEMPERATURE OF FUEL	F	
13	GAS TEMP. LEAVING (Boiler) (Econ.) (Air Htr.)	F	
	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	
16	ENTHALPY OF (SATURATED) (SUPERHEATED) STM.	Btu/lb	
7	ENTHALPY OF SAT. FEED TO (BOILER) (ECON.)	Btu/lb	
	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	
9	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	
21	HEAT ABS/LB R. H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	421
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	.6182
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	12.0

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	
27	REHEAT STEAM FLOW	lb/hr	
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	
29	TOTAL HEAT INPUT $\frac{(\text{Item 28} \times \text{Item 41})}{1000}$	kB/hr	
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	
3	TOTAL HEAT UTPUT $\frac{(\text{Item 26} \times \text{Item 20}) + (\text{Item 27} \times \text{Item 21})}{1000}$ + Item 30	kB/hr	

FLUE GAS ANAL. (BOILER) (ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	13.3
33	O_2	% VOL	3.3
34	CO	% VOL	
35	N_2 (BY DIFFERENCE)	% VOL	83.4
36	EXCESS AIR	%	

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	8.48
38	VOL MATTER	34.47
39	FIXED CARBON	44.60
40	ASH	12.45
	TOTAL	100.00
41	Btu per lb AS FIRED	11863 @C.V. 11275 @C.P.
42	ASH SOFT TEMP.* ASTM METHOD	

	OIL	
51	FLASH POINT F*	
52	Sp. Gravity Deg. API*	
53	VISCOSITY AT BURNER SSU* SSF	
44	TOTAL HYDROGEN % wt	
41	Btu per lb	

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	62.18
44	HYDROGEN	4.37
45	OXYGEN	7.41
46	NITROGEN	1.14
47	SULPHUR	3.89
40	ASH	12.45
37	MOISTURE	8.56
	TOTAL	100.00

	GAS	% VOL
54	CO	
55	CH_4 METHANE	
56	C_2H_2 ACETYLENE	
57	C_2H_4 ETHYLENE	
58	C_2H_6 ETHANE	
59	H_2S	
60	CO_2	
61	H_2 HYDROGEN	
	TOTAL	
	TOTAL HYDROGEN % wt	
62	DENSITY 68 F ATM. PRESS.	
63	Btu PER CU FT	
41	Btu PER LB	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	
49	FINENESS % THRU 50 M*	
50	FINENESS % THRU 200 M*	

64 INPUT-OUTPUT EFFICIENCY OF UNIT % $\frac{\text{ITEM 31} \times 100}{\text{ITEM 29}}$

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	720	6.39
66	HEAT LOSS DUE TO MOISTURE IN FUEL	96.0	.85
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	445	3.95
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	52.4	.46
69	HEAT LOSS DUE TO RADIATION		.21
70	UNMEASURED LOSSES		1.5
71	TOTAL		13.36
72	EFFICIENCY = (100 – Item 71)		86.64

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

TEST NO. B005 2 BOILER NO. DATE 6-23-78
ER OF PLANT CRIST LOCATION
CONDUCTED BY OBJECTIVE OF TEST DURATION
BOILER, MAKE & TYPE RATED CAPACITY
STOKER, TYPE & SIZE
PULVERIZER, TYPE & SIZE BURNER, TYPE & SIZE
FUEL USED MINE COUNTY STATE SIZE AS FIRED

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	
2	STEAM PRESSURE AT S. H. OUTLET	psia	
3	STEAM PRESSURE AT R. H. INLET	psia	
4	STEAM PRESSURE AT R. H. OUTLET	psia	
5	STEAM TEMPERATURE AT S. H. OUTLET	F	
6	STEAM TEMPERATURE AT R.H. INLET	F	
7	STEAM TEMPERATURE AT R.H. OUTLET	F	
8	WATER TEMP. ENTERING (ECON.)(BOILER)	F	
9	STEAM QUALITY % MOISTURE OR P. P. M.		
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	
11	TEMP. AIR FOR COMBUSTION (This is Reference Temperature) †	F	
12	TEMPERATURE OF FUEL	F	
13	GAS TEMP. LEAVING (Boiler) (Econ.) (Air Htr.)	F	
	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	
16	ENTHALPY OF (SATURATED) (SUPERHEATED) STM.	Btu/lb	
17	ENTHALPY OF SAT. FEED TO (BOILER) (ECON.)	Btu/lb	
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	463
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	.6115
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	9.96

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	
27	REHEAT STEAM FLOW	lb/hr	
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	
29	TOTAL HEAT INPUT $\frac{\text{(Item 28 x Item 41)}}{1000}$	kB/hr	
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	
31	TOTAL HEAT OUTPUT $\frac{\text{(Item 26 x Item 20)+(Item 27 x Item 21)}}{1000}$ + Item 30	kB/hr	

FLUE GAS ANAL. (BOILER) (ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	16.0
33	O_2	% VOL	2.0
34	CO	% VOL	
35	N_2 (BY DIFFERENCE)	% VOL	82.0
36	EXCESS AIR	%	

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	8.07	51	FLASH POINT F*	
38	VOL MATTER	33.43	52	Sp. Gravity Deg. API*	
39	FIXED CARBON	44.18	53	VISCOSITY AT SSU* BURNER SSF	
40	ASH	14.32	44	TOTAL HYDROGEN % wt	
	TOTAL	100.00	41	Btu per lb	
41	Btu per lb AS FIRED	11083	@C.V 11044 @C.P.		
42	ASH SOFT TEMP.* ASTM METHOD			GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	
43	CARBON	61.61	55	CH_4 METHANE	
44	HYDROGEN	4.09	56	C_2H_2 ACETYLENE	
45	OXYGEN	7.35	57	C_2H_4 ETHYLENE	
46	NITROGEN	1.12	58	C_2H_6 ETHANE	
47	SULPHUR	3.39	59	H_2S	
40	ASH	14.32	60	CO_2	
37	MOISTURE	8.12	61	H_2 HYDROGEN	
	TOTAL	100.00		TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	
48	GRINDABILITY INDEX*		62	DENSITY 68 F ATM. PRESS.	
49	FINENESS % THRU 50 M*		63	Btu PER CU FT	
50	FINENESS % THRU 200 M*		41	Btu PER LB	

64 INPUT-OUTPUT EFFICIENCY OF UNIT % $\frac{\text{ITEM 31} \times 100}{\text{ITEM 29}}$

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	588	5.32
66	HEAT LOSS DUE TO MOISTURE IN FUEL	91	.82
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	415	3.76
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	66	.60
69	HEAT LOSS DUE TO RADIATION		.21
70	UNMEASURED LOSSES		1.5
71	TOTAL		12.21
72	EFFICIENCY = (100 – Item 71)		87.79

*Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

APPENDIX B

ANALYTICAL PROCEDURES

Level 1 Organic Analysis Procedure Modification

Pilot Studies Protocol

Reasons for this Modification:

The original Level 1 Organic Analysis Procedure, as specified in the June 1976 Procedures Manual, was designed in a manner which provided qualititative compound class identification and quantitative (gravimetric) data for those components of a sample that are retained when an organic sample extract is evaporated to dryness. For more volatile sample components, only quantitative information (quantities of material in defined boiling point ranges) was to be obtained. It was implicitly assumed that all compounds with boiling points $>$ ca. 220°C (C_{13} and higher normal hydrocarbon range) would be retained and carried through the LC-IR-LRMS procedure, while those boiling below 220°C (C_{12} and lower normal hydrocarbons down to C_7*) might be lost during sample evaporation to dryness.

New experimental data have shown that:

1. The range of material lost when the sample is evaporated to dryness for the gravimetric analysis and preparation of the LC sample is somewhat higher than anticipated: It is probably only C_{16} and higher (rather than C_{13} and higher) hydrocarbons that are retained. The C_{16} n-alkane boiling point is about 275°C.
2. Many of the compounds which are considered to be of concern in environmental assessment as a whole (not just Level 1) are in the boiling point range that would correspond to loss prior to LC, according to present procedures. Thus, no compound class information would be available from Level 1 to indicate the possible presence or to confirm the absence of significant amounts of these materials.

A revised procedure for Level 1 has been devised and subjected to limited experimental validation. The principal feature of this procedure, compared to the original, is that the organic extract is not evaporated to

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*C_1-C_6 are to be done by on-site GC.

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dryness prior to LC and/or LRMS analyses. Two new sample handling steps are required:

- A quantitative assay procedure, TCO (total chromatographable organics) to complement the gravimetric analysis, and give quantitative data on C_7-C_{16} range materials.
- A solvent exchange step to transfer the sample from CH_2Cl_2 extract to a non-polar solvent and allow lower boiling material ($>C_7$) to go through LC and subsequent steps.

A new flow diagram is shown in Figure 1. The two new procedures are described on the following pages.

The total mass data for extracted samples is now taken as the sum of the value determined from the TCO and gravimetric assay. (TCO + GRAV)

Note that the C7 - C12 GC assay is now not required.

Both qualitative and quantitative data are expected to be obtained by this scheme for all materials boiling above the C_7 paraffin.

All other provisions, criteria and instruction of the Procedures Manual apply except for the noted changes.

TCO

Analyze a 1 μℓ aliquot of solution by GC using a flame ionization detector. A 6 ft x 1/8 in. O.D. column of 10 percent OV-101 on 100/120 mesh Supelcoport has been used successfully for this analysis. Other silicon phases (OV-1, etc.) may work as well, but a 10 percent loading is recommended. The GC should be operated isothermally at about 30°C - or room temperature - for 5 minutes after sample injection and then programmed at approximately 20°C per minute to 250°C and held at 250°C as long as necessary for complete elution of sample.

Integrator should be set to begin integration at heptane (C_7) peak maxima and terminate at the peak maxima of the heptadecane (C_{17}) peak, as determined from calibration standards. In this manner the integrated area will cover material in the boiling range of C_7-C_{16}.

Calibration should be done with a mixture containing a homologous series of hydrocarbons from C_7 to C_{16}. Standards should be prepared to cover the concentration range to be studied.

Solvent Exchange:

Place 1-5 mℓ of CH_2Cl_2 extract containing 15-100 mg of solute (TCO + GRAV), preferably 100 mg, in graduated centrifuge tube or K-D

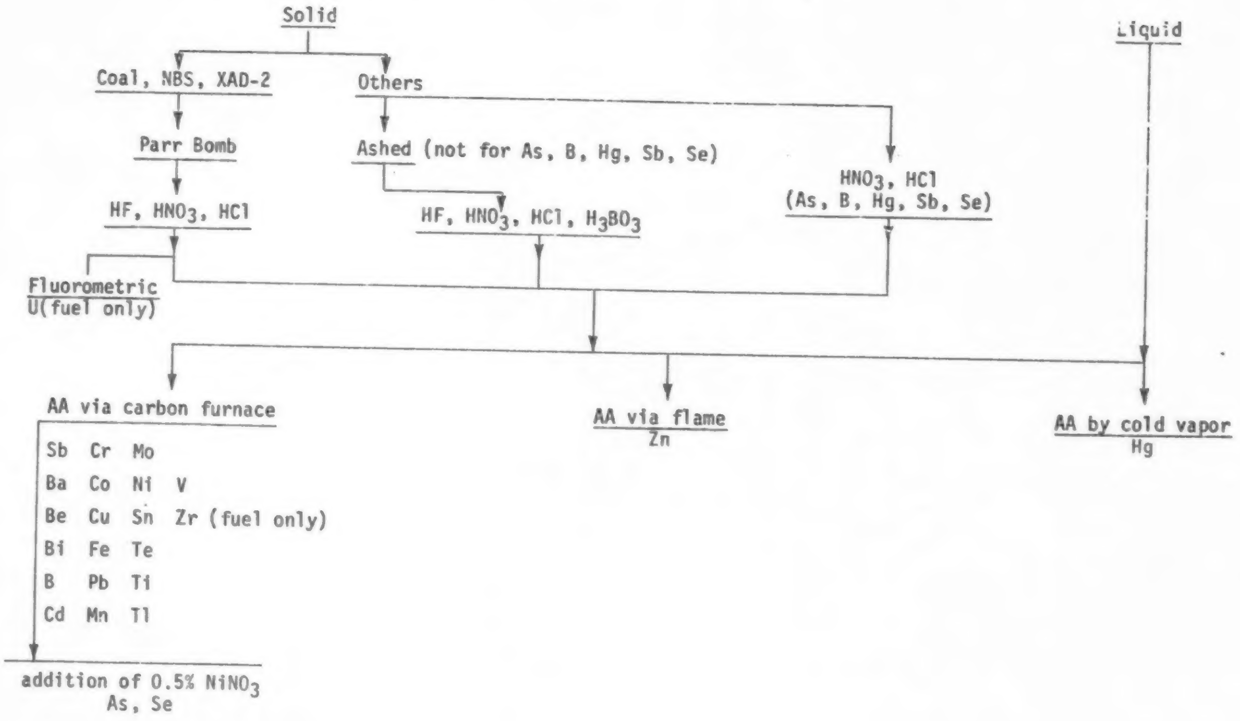
Solid
Liquid
Coal, NBS, XAD-2
Others
Parr Bomb
Ashed (not for As, B, Hg, Sb, Se)
HF, HNO3, HCl
HF, HNO3, HCl, H3BO3
HNO3, HCl
(As, B, Hg, Sb, Se)
Fluorometric
U(fuel only)
AA via carbon furnace
Sb Cr Mo
Ba Co Ni V
Be Cu Sn Zr (fuel only)
Bi Fe Te
B Pb Ti
Cd Mn Tl
addition of 0.5% NiNO3
As, Se
AA via flame
Zn
AA by cold vapor
Hg

Figure 1. Elemental analysis flow sheet.

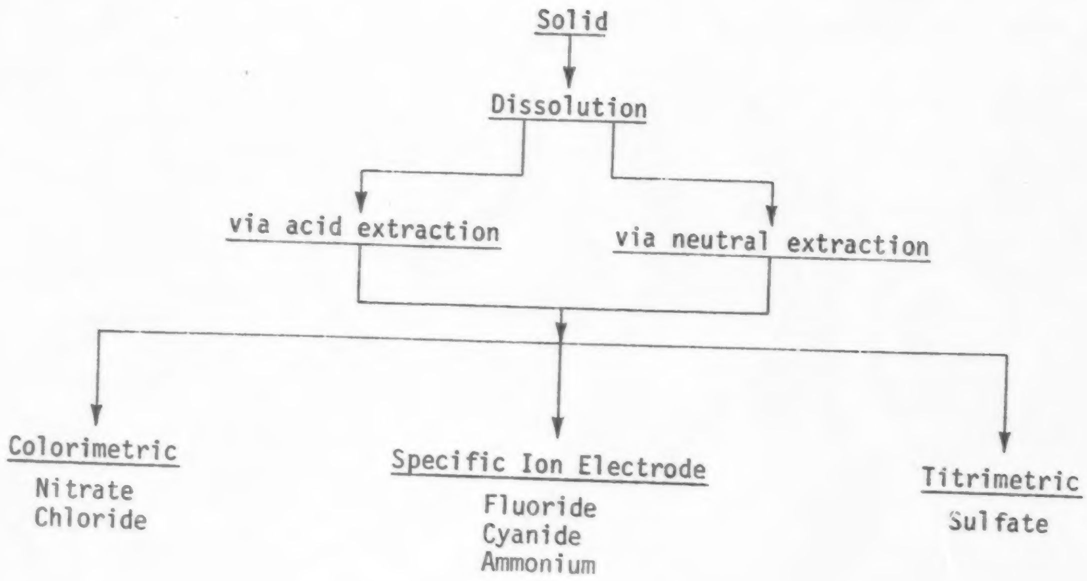
Solid
Dissolution
via acid extraction
via neutral extraction
Colorimetric
Nitrate
Chloride
Specific Ion Electrode
Fluoride
Cyanide
Ammonium
Titrimetric
Sulfate

Figure 2. Anions plus ammonium analysis flow sheet.

receiver. Add 200 mg of silica gel prepared as for the LC column. Evaporate if necessary to reduce volume to 1 mℓ.

Add 1 mℓ cyclopentane and mix by gentle agitation. Again reduce volume to 1 mℓ by evaporation.

Add 1 mℓ more of cyclopentane and mix. Reduce volume to 1 mℓ again.

Transfer cyclopentane and silica gel (a Pasteur pipette works well) to top of previously prepared LC column.

Run column as directed in Manual, rinsing graduated receiver with fresh solvents as they are introduced in the elution sequence.

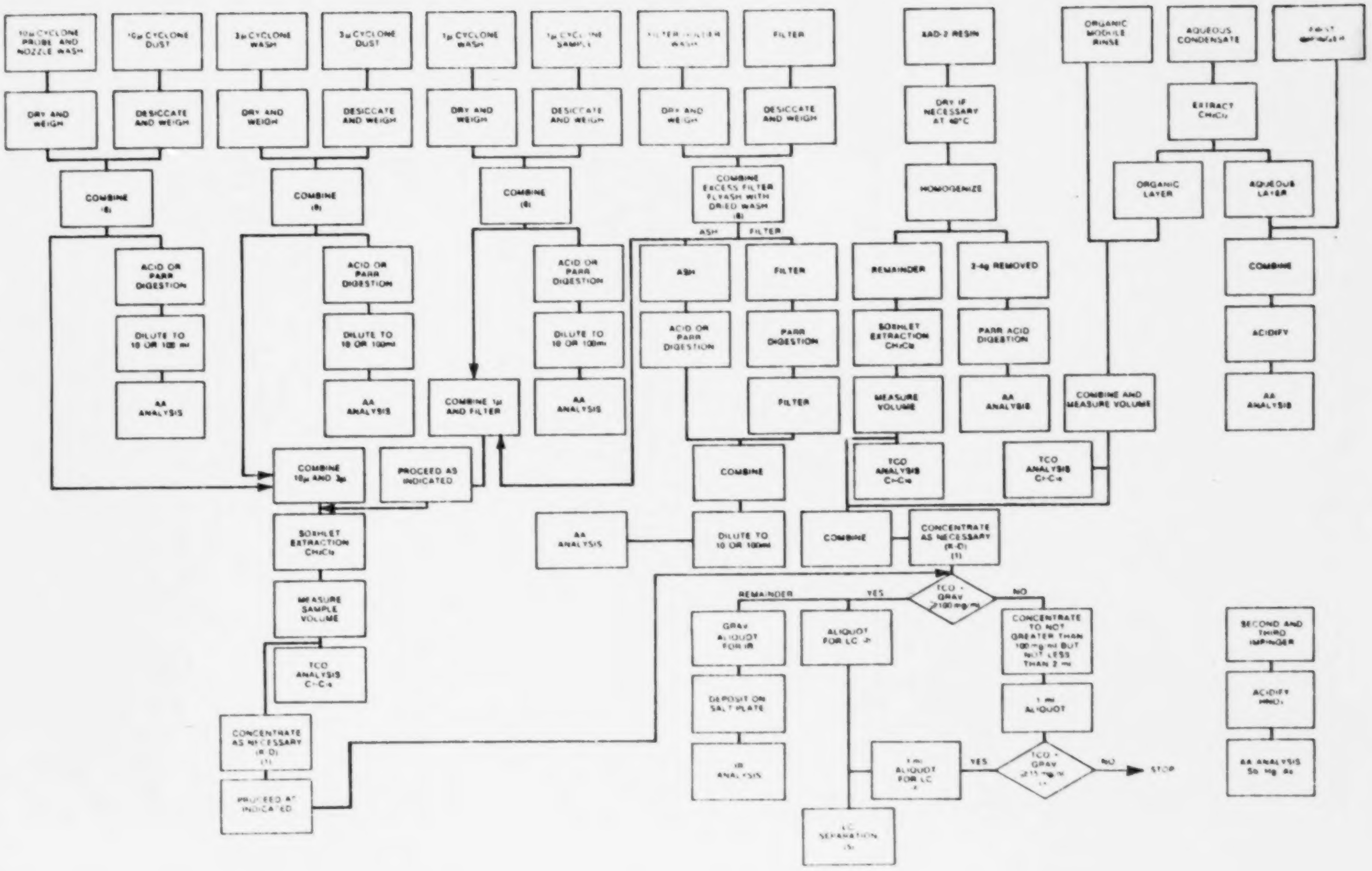
10µ CYCLONE PROBE AND NOZZLE WASH
10µ CYCLONE DUST
3µ CYCLONE WASH
3µ CYCLONE DUST
1µ CYCLONE WASH
1µ CYCLONE SAMPLE
FILTER HOLDER WASH
FILTER
XAD-2 RESIN
ORGANIC MODULE RINSE
AQUEOUS CONDENSATE
DRY AND WEIGH
DESICCATE AND WEIGH
DRY IF NECESSARY AT 60°C
EXTRACT CH₂Cl₂
COMBINE (6)
COMBINE EXCESS FILTER FLYASH WITH DRIED WASH (6)
ASH
FILTER
HOMOGENIZE
ORGANIC LAYER
AQUEOUS LAYER
ACID OR PARR DIGESTION
PARR DIGESTION
REMAINDER
2-4g REMOVED
COMBINE
DILUTE TO 10 OR 100 ml
SOXHLET EXTRACTION CH₂Cl₂
PARR ACID DIGESTION
ACIDIFY
AA ANALYSIS
MEASURE VOLUME
COMBINE AND MEASURE VOLUME
COMBINE 1µ AND FILTER
COMBINE 10µ AND 3µ
PROCEED AS INDICATED
TCO ANALYSIS C₇-C₁₆
MEASURE SAMPLE VOLUME
CONCENTRATE AS NECESSARY (K-D) (1)
PROCEED AS INDICATED
TCO + GRAV ≥100 mg/ml
YES
NO
REMAINDER
GRAV ALIQUOT FOR IR
ALIQUOT FOR LC
CONCENTRATE TO NOT GREATER THAN 100 mg/ml BUT NOT LESS THAN 2 ml
DEPOSIT ON SALT PLATE
IR ANALYSIS
1 ml ALIQUOT
1 ml ALIQUOT FOR LC
TCO + GRAV ≥15 mg
STOP
LC SEPARATION (5)
SECOND AND THIRD IMPINGER
ACIDIFY HNO₃
AA ANALYSIS Sb, Hg, As

Figure 3. SASS analysis procedures.

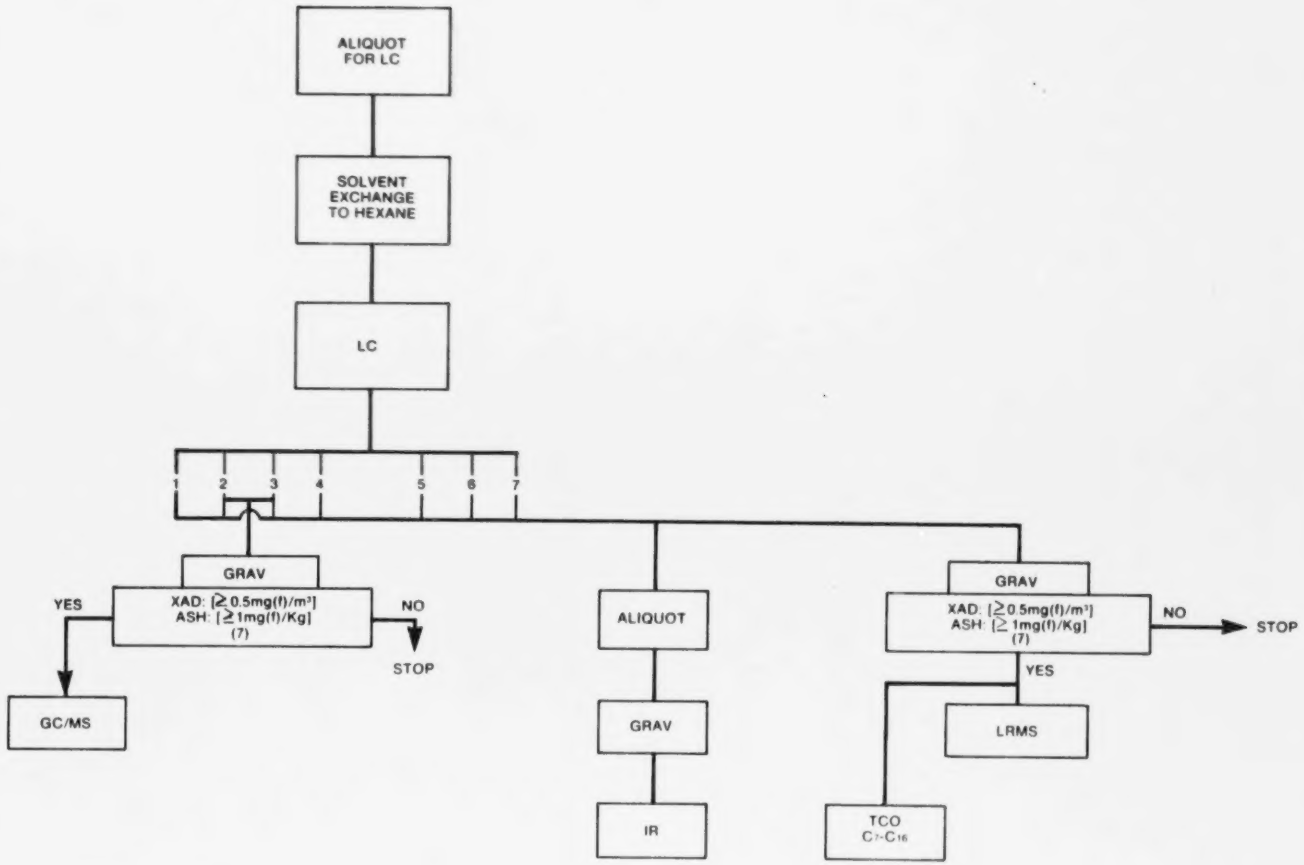
ALIQUOT FOR LC
SOLVENT EXCHANGE TO HEXANE
LC
1
2
3
4
5
6
7
GRAV
XAD: [≥0.5mg(f)/m³]
ASH: [≥1mg(f)/Kg]
(7)
YES
NO
STOP
GC/MS
ALIQUOT
GRAV
IR
GRAV
XAD: [≥0.5mg(f)/m³]
ASH: [≥1mg(f)/Kg]
(7)
NO
STOP
YES
LRMS
TCO
C7-C16

Figure 4. SASS analysis procedure liquid chromatography.

APPENDIX C

TRACE ELEMENT CONCENTRATION

NOMENCLATURE

DSCM	Dry Standard Cubic Meter
G	Gram
J	Joule
MCG	Microgram
PPM	Parts per million by weight
SEC	Second
<	Less than
*	Sample not analyzed for the particular element/or ionic specie
N	Sample not analyzed
-	Concentration in the sample is less than the concentration in the blank

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COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - COAL INLET

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .200	< .200	< .200
ARSENIC	1.70	.900	.900
BARIUM	93.0	60.0	76.0
BERYLLIUM	1.40	1.20	1.20
BISMUTH	< 3.00	< 2.00	< 2.00
BORON	* .000	* .000	* .000
CADMIUM	< .100+00	< .100+00	< .100+00
CHROMIUM	22.0	17.0	16.0
COBALT	4.60	3.50	4.60
COPPER	11.0	11.0	9.80
IRON	.230+05	.260+05	.180+05
LEAD	18.0	< 6.00	< 5.00
MANGANESE	73.0	73.0	52.0
MERCURY	.700-01	.170	.110
MOLYBDENUM	8.70	13.0	8.10
NICKEL	23.0	18.0	12.0
SELENIUM	1.30	1.00	1.20
TELLURIUM	< .200	< .200	< .200
THALLIUM	< 4.00	< 3.00	< 3.00
TIN	2.20	1.80	63.0
TITANIUM	.166+04	.103+04	.132+04
URANIUM	* .000	* .000	* .000
VANADIUM	38.0	60.0	31.0
ZINC	49.0	51.0	43.0
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - BOTTOM ASH

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .600	< .600	< .600
ARSENIC	< 3.00	< 8.00	< 3.00
BARIUM	270.	770.	160.
BERYLLIUM	9.00	6.50	7.70
BISMUTH	< 6.00	230.	< 6.00
BORON	< .100+00	.200	.200
CADMIUM	< .300-01	.480	< .300-01
CHROMIUM	75.0	100.	74.0
COBALT	5.00	< .100+00	2.00
COPPER	60.0	23.0	53.0
IRON	.410+05	.190+06	.430+05
LEAD	34.0	23.0	21.0
MANGANESE	890.	.110+04	970.
MERCURY	< .600	< .600	< .700
MOLYBDENUM	< 6.00	< 3.00	< .600
NICKEL	54.0	48.0	53.0
SELENIUM	.700	1.00	2.50
TELLURIUM	< .900	.400	< .900
THALLIUM	< 400.	< 400.	< 400.
TIN	< 2.00	< 4.00	< 2.00
TITANIUM	.240+04	.510+04	.230+04
URANIUM	* .000	* .000	* .000
VANADIUM	240.	340.	220.
ZINC	150.	310.	190.
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP INLET
10 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	2.00	< .300	< .300
ARSENIC	28.0	28.0	26.0
BARIUM	.140+04	550.	.160+04
BERYLLIUM	10.0	13.0	10.0
BISMUTH	< 3.00	540.	< 3.00
BORON	490.	450.	370.
CADMIUM	2.90	2.30	2.20
CHROMIUM	400.	160.	250.
COBALT	35.0	49.0	44.0
COPPER	76.0	60.0	73.0
IRON	.220+05	.140+06	.320+05
LEAD	78.0	.100+04	83.0
MANGANESE	830.	740.	710.
MERCURY	< .500	.400	< .400
MOLYBDENUM	13.0	2.00	7.00
NICKEL	280.	80.0	190.
SELENIUM	1.80	.900	1.70
TELLURIUM	< .600	.600	< .600
THALLIUM	< 400.	< 400.	< 400.
TIN	< 1.00	< 2.00	< 1.00
TITANIUM	.440+04	.420+04	.430+04
URANIUM	* .000	* .000	* .000
VANADIUM	220.	430.	210.
ZINC	510.	240.	340.
ZIRCONIUM	* .000	* .000	* .000
ANION			
CHLORIDE	* .000	* .000	35.0
FLUORIDE	* .000	* .000	2.90
CYANIDE	* .000	* .000	< .100+00
NITRATE	* .000	* .000	8.50
SULFATE	* .000	* .000	260.
AMMONIUM	* .000	* .000	8.90

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP INLET
3 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.900	< .300	1.90
ARSENIC	72.0	78.0	64.0
BARIUM	.220+04	660.	.240+04
BERYLLIUM	13.0	16.0	12.0
BISMUTH	< 3.00	340.	< 3.00
BORON	680.	430.	310.
CADMIUM	4.90	1.60	4.90
CHROMIUM	160.	200.	180.
COBALT	33.0	58.0	41.0
COPPER	81.0	75.0	83.0
IRON	.210+05	.110+06	.220+05
LEAD	130.	180.	160.
MANGANESE	740.	760.	940.
MERCURY	< .400	< .500	< .400
MOLYBDENUM	10.0	6.00	8.00
NICKEL	120.	100.	120.
SELENIUM	1.30	< .100+00	5.40
TELLURIUM	< .600	.200	< .600
THALLIUM	< 400.	< 400.	< 400.
TIN	< 1.00	< 2.00	2.00
TITANIUM	.460+04	.480+04	.410+04
URANIUM	* .000	* .000	* .000
VANADIUM	310.	620.	260.
ZINC	630.	400.	.110+04
ZIRCONIUM	* .000	* .000	* .000
ANION			
CHLORIDE	* .000	* .000	23.2
FLUORIDE	* .000	* .000	1.80
CYANIDE	* .000	* .000	< .100+00
NITRATE	* .000	* .000	1.40
SULFATE	* .000	* .000	2.84
AMMONIUM	* .000	* .000	.300

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP INLET
1 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	14.0	< .300	4.70
ARSENIC	130.	150.	120.
BARIUM	.190+04	.260+04	.280+04
BERYLLIUM	16.0	15.0	16.0
BISMUTH	< 3.00	39.0	< 3.00
BORON	330.	350.	390.
CADMIUM	14.0	5.50	10.0
CHROMIUM	300.	270.	240.
COBALT	61.0	68.0	49.0
COPPER	120.	69.0	110.
IRON	.210+05	.130+06	.240+05
LEAD	220.	290.	250.
MANGANESE	970.	770.	.120+04
MERCURY	< .400	< .400	< .400
MOLYBDENUM	14.0	6.00	11.0
NICKEL	150.	140.	150.
SELENIUM	1.50	< .100+00	2.50
TELLURIUM	< .600	.300	< .600
THALLIUM	< 400.	< 400.	< 400.
TIN	4.00	3.00	10.0
TITANIUM	.660+04	.670+04	.670+04
URANIUM	* .000	* .000	* .000
VANADIUM	480.	900.	380.
ZINC	.120+04	800.	.110+04
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP INLET FILTER

TRACE ELEMENT CATION	TEST CONDITION BASELINE	 BOOS1	 BOOS2
ANTIMONY	320.	63.0	380.
ARSENIC	240.	750.	170.
BARIUM	780.	400.	550.
BERYLLIUM	15.0	19.0	16.0
BISMUTH	< 2.00	180.	< 2.00
BORON	* .000	* .000	* .000
CADMIUM	56.0	31.0	59.0
CHROMIUM	250.	120.	170.
COBALT	20.0	95.0	28.0
COPPER	83.0	150.	81.0
IRON	.100+05	.690+05	.160+05
LEAD	80.0	160.	96.0
MANGANESE	420.	330.	.250
MERCURY	< .600	< .600	< .600
MOLYBDENUM	490.	510.	510.
NICKEL	200.	69.0	52.0
SELENIUM	10.0	3.70	18.0
TELLURIUM	3.80	3.30	4.70
THALLIUM	12.0	38.0	10.0
TIN	10.0	< 10.0	60.0
TITANIUM	.140+04	.380+04	.230+04
URANIUM	* .000	* .000	* .000
VANADIUM	.110+04	.200+04	980.
ZINC	540.	.110+04	.180+04
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP INLET
XAD-2 RESIN

TRACE ELEMENT	TEST CONDITION					
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY	<	.500	*	.000	<	.500
ARSENIC	<	.600	*	.000	<	.500
BARIUM		25.0	*	.000		130.
BERYLLIUM	<	.500	*	.000	<	.500
BISMUTH	<	.400	*	.000	<	.300
BORON		39.0	*	.000	<	20.0
CADMIUM	<	.200-01	*	.000		.900-01
CHROMIUM		14.0	*	.000		5.60
COBALT	<	20.0	*	.000		18.0
COPPER	<	.400-01	*	.000		1.80
IRON		3.80	*	.000		230.
LEAD		1.40	*	.000		1.40
MANGANESE		1.70	*	.000		.340
MERCURY	<	.700	*	.000	<	.600
MOLYBDENUM	<	9.00	*	.000	<	7.00
NICKEL	<	7.00	*	.000	<	6.00
SELENIUM	<	.300	*	.000		.400
TELLURIUM	<	.700	*	.000	<	.700
THALLIUM		5.40	*	.000		4.70
TIN	<	.400	*	.000	<	.300
TITANIUM	<	4.00	*	.000	<	4.00
URANIUM	*	.000	*	.000	*	.000
VANADIUM	<	9.00	*	.000	<	8.00
ZINC	<	3.00	*	.000	<	3.00
ZIRCONIUM	*	.000	*	.000	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP INLET
FIRST IMPINGER

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .200-02	* .000	< .200-02
ARSENIC	.320-01	* .000	.270-01
BARIUM	< .500	* .000	1.10
BERYLLIUM	< .200-02	* .000	.500-03
BISMUTH	.300-02	* .000	.570-02
BORON	29.0	* .000	30.0
CADMIUM	< .700-04	* .000	.480-02
CHROMIUM	48.0	* .000	3.90
COBALT	.540	* .000	.380
COPPER	1.00	* .000	.710
IRON	5.80	* .000	57.0
LEAD	.220-01	* .000	21.0
MANGANESE	5.00	* .000	4.20
MERCURY	.300-01	* .000	< .100-01
MOLYBDENUM	3.40	* .000	2.30
NICKEL	29.0	* .000	1.10
SELENIUM	.600	* .000	.670
TELLURIUM	< .500-02	* .000	< .400-02
THALLIUM	.120-01	* .000	.860-02
TIN	.750-01	* .000	< .100-01
TITANIUM	< 10.0	* .000	< 10.0
URANIUM	* .000	* .000	* .000
VANADIUM	.880-01	* .000	.130
ZINC	2.90	* .000	2.30
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP INLET
2ND & 3RD IMPINGERS

TRACE ELEMENT CATION		TEST CONDITION BASELINE		BOOS1		BOOS2
ANTIMONY	<	.300-02	*	.000	<	.300-02
ARSENIC	<	.500-02	*	.000		.120-01
BARIUM	*	.000	*	.000	*	.000
BERYLLIUM	*	.000	*	.000	*	.000
BISMUTH	*	.000	*	.000	*	.000
BORON	*	.000	*	.000	*	.000
CADMIUM	*	.000	*	.000	*	.000
CHROMIUM	*	.000	*	.000	*	.000
COBALT	*	.000	*	.000	*	.000
COPPER	*	.000	*	.000	*	.000
IRON	*	.000	*	.000	*	.000
LEAD	*	.000	*	.000	*	.000
MANGANESE	*	.000	*	.000	*	.000
MERCURY	<	.600-02	*	.000	<	.300
MOLYBDENUM	*	.000	*	.000	*	.000
NICKEL	*	.000	*	.000	*	.000
SELENIUM	*	.000	*	.000	*	.000
TELLURIUM	*	.000	*	.000	*	.000
THALLIUM	*	.000	*	.000	*	.000
TIN	*	.000	*	.000	*	.000
TITANIUM	*	.000	*	.000	*	.000
URANIUM	*	.000	*	.000	*	.000
VANADIUM	*	.000	*	.000	*	.000
ZINC	*	.000	*	.000	*	.000
ZIRCONIUM	*	.000	*	.000	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP HOPPER ASH

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .500	< .700	< .500
ARSENIC	< 3.00	20.0	< 3.00
BARIUM	190.	.120+04	59.0
BERYLLIUM	7.40	9.00	6.50
BISMUTH	< 6.00	570.	7.00
BORON	370.	390.	390.
CADMIUM	4.10	1.60	1.40
CHROMIUM	130.	120.	110.
COBALT	< 2.00	78.0	< 2.00
COPPER	48.0	42.0	45.0
IRON	.330+05	.160+06	.280+05
LEAD	62.0	60.0	68.0
MANGANESE	.120+04	.120+04	600.
MERCURY	< .800	< .700	.900
MOLYBDENUM	< 6.00	< 3.00	24.0
NICKEL	150.	46.0	89.0
SELENIUM	1.00	1.00	2.80
TELLURIUM	< .900	< .200	< .900
THALLIUM	< 400.	< 400.	< 400.
TIN	3.00	< 5.00	< 2.00
TITANIUM	.400+04	.540+04	.260+04
URANIUM	* .000	* .000	* .000
VANADIUM	230.	360.	210.
ZINC	210.	260.	150.
ZIRCONIUM	170.	140.	* .000
ANION			
CHLORIDE	23.0	29.2	< 5.20
FLUORIDE	10.1	2.80	2.00
CYANIDE	< .100+00	< .100+00	< .100+00
NITRATE	14.0	5.60	43.5
SULFATE	196.	263.	212.
AMMONIUM	2.30	5.80	5.40

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP OUTLET
10 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.800	.400	< .300
ARSENIC	9.50	10.0	9.20
BARIUM	.230+04	860.	.220+04
BERYLLIUM	10.0	10.0	8.10
BISMUTH	< 3.00	24.0	< 3.00
BORON	290.	170.	180.
CADMIUM	2.50	.970	1.40
CHROMIUM	120.	120.	110.
COBALT	35.0	17.0	41.0
COPPER	68.0	45.0	91.0
IRON	.160+05	.220+06	.330+05
LEAD	46.0	34.0	46.0
MANGANESE	880.	800.	800.
MERCURY	< .400	.500	.400
MOLYBDENUM	5.00	2.00	4.00
NICKEL	98.0	110.	87.0
SELENIUM	.800	< .100+00	1.70
TELLURIUM	< .600	< .100+00	< .600
THALLIUM	< 400.	< 400.	< 400.
TIN	1.00	< 2.00	< 1.00
TITANIUM	.380+04	.310+04	.490+04
URANIUM	* .000	* .000	* .000
VANADIUM	210.	410.	190.
ZINC	280.	150.	310.
ZIRCONIUM	* .000	* .000	* .000
ANION			
CHLORIDE	23.3	43.7	* .000
FLUORIDE	2.40	2.90	* .000
CYANIDE	< .100+00	< .100+00	* .000
NITRATE	7.00	26.3	* .000
SULFATE	236.	246.	* .000
AMMONIUM	4.90	1.40	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP OUTLET
3 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	4.20	< .300	.500
ARSENIC	64.0	74.0	56.0
BARIUM	.150+04	980.	.200+04
BERYLLIUM	14.0	14.0	12.0
BISMUTH	< 3.00	520.	< 3.00
BORON	410.	470.	380.
CADMIUM	5.60	1.80	3.60
CHROMIUM	180.	180.	120.
COBALT	43.0	39.0	41.0
COPPER	91.0	74.0	91.0
IRON	.230+05	.120+06	.240+05
LEAD	130.	140.	130.
MANGANESE	740.	730.	710.
MERCURY	< .400	< .400	< .400
MOLYBDENUM	< 3.00	3.00	8.00
NICKEL	120.	110.	110.
SELENIUM	1.30	.600	1.10
TELLURIUM	< .600	.400	< .600
THALLIUM	< 400.	< 400.	< 400.
TIN	.300	< 2.00	1.00
TITANIUM	590.	.550+04	.490+04
URANIUM	* .000	* .000	* .000
VANADIUM	310.	490.	260.
ZINC	680.	320.	600.
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP OUTLET
1 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	17.0	.500	13.0
ARSENIC	150.	150.	130.
BARIUM	.200+04	.280+04	.420+04
BERYLLIUM	18.0	21.0	14.0
BISMUTH	< 3.00	570.	< 6.00
BORON	* .000	150.	370.
CADMIUM	14.0	5.10	11.0
CHROMIUM	280.	260.	250.
COBALT	49.0	60.0	37.0
COPPER	120.	81.0	110.
IRON	.240+05	.120+06	.200+05
LEAD	230.	260.	250.
MANGANESE	.110+04	770.	600.
MERCURY	< .400	< .400	< .700
MOLYBDENUM	18.0	6.00	21.0
NICKEL	150.	140.	140.
SELENIUM	< .200	.400	< .400
TELLURIUM	< .600	.500	< .900
THALLIUM	< 400.	< 400.	< 400.
TIN	3.00	< 2.00	27.0
TITANIUM	.570+04	.550+04	.520+04
URANIUM	* .000	* .000	* .000
VANADIUM	560.	880.	440.
ZINC	.110+04	800.	.150+04
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP OUTLET FILTER

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	410.	41.0	250.
ARSENIC	320.	550.	300.
BARIUM	350.	310.	810.
BERYLLIUM	17.0	12.0	11.0
BISMUTH	< 3.00	71.0	< 2.00
BORON	* .000	* .000	* .000
CADMIUM	90.0	24.0	41.0
CHROMIUM	230.	120.	300.
COBALT	< 3.00	41.0	31.0
COPPER	130.	5.60	120.
IRON	.240+05	.420+05	.200+05
LEAD	660.	96.0	110.
MANGANESE	.540	240.	450.
MERCURY	< .600	.900	< .600
MOLYBDENUM	570.	350.	400.
NICKEL	170.	56.0	110.
SELENIUM	16.0	2.70	18.0
TELLURIUM	2.80	1.00	3.20
THALLIUM	21.0	27.0	8.20
TIN	< 7.00	< 10.0	20.0
TITANIUM	.140+04	.200+04	.270+04
URANIUM	* .000	* .000	* .000
VANADIUM	.120+04	.140+04	710.
ZINC	540.	720.	.100+04
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP OUTLET
XAD-2 RESIN

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .400	.730	< .400
ARSENIC	< .500	< 2.00	< .500
BARIUM	110.	15.0	34.0
BERYLLIUM	< .300	< .300	< .400
BISMUTH	< .300	< .500	.770
BORON	27.0	150.	< 10.0
CADMIUM	< .200-01	.970	.300-01
CHROMIUM	7.00	22.0	8.70
COBALT	< 20.0	< 5.00	< 20.0
COPPER	1.40	< .800-01	< 1.00
IRON	3.60	360.	6.30
LEAD	< .300-01	< .200	< .300-01
MANGANESE	.120	7.60	.430
MERCURY	< .500	< .700	< .500
MOLYBDENUM	< 6.00	< 5.00	< 6.00
NICKEL	< 5.00	< .200	< 5.00
SELENIUM	9.30	4.40	5.40
TELLURIUM	< .700	< .200	< .700
THALLIUM	5.50	< .600	5.30
TIN	1.40	< .800	.600
TITANIUM	< 3.00	150.	< 3.00
URANIUM	* .000	* .000	* .000
VANADIUM	< .600	< .400	< 5.00
ZINC	< 3.00	< 6.00	< 4.00
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP OUTLET
FIRST IMPINGER

TRACE ELEMENT		TEST CONDITION	
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .200-02	< .300-02	< .200-02
ARSENIC	.330-01	.420-01	.310-01
BARIUM	< .500	1.70	1.10
BERYLLIUM	< .200-02	< .100-02	.400-03
BISMUTH	< .200-02	< .300-02	.300-02
BORON	28.0	26.0	28.0
CADMIUM	.450-02	.320-01	< .100-03
CHROMIUM	52.0	89.0	3.40
COBALT	.700	.890	.250
COPPER	.150	.600-03	.600-01
IRON	58.0	330.	42.0
LEAD	.580-02	< .100-02	< .200-03
MANGANESE	6.40	2.80	2.20
MERCURY	.200-01	< .200	< .100-01
MOLYBDENUM	3.70	.670	.320
NICKEL	22.0	39.0	14.0
SELENIUM	.550	.410	.590
TELLURIUM	< .500-02	.400-02	.100-01
THALLIUM	.130-01	< .200-02	.640-02
TIN	.200-01	< .300-01	.200-01
TITANIUM	< 10.0	< .100-01	< 10.0
URANIUM	* .000	* .000	* .000
VANADIUM	.200-01	.110	.690-01
ZINC	< 1.00	.110	< 1.00
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - PPM - ESP OUTLET
2ND & 3RD IMPINGERS

TRACE ELEMENT CATION		BASELINE		BOOS1		BOOS2
				TEST CONDITION		
ANTIMONY		.300-02	<	.300-02	<	.300-02
ARSENIC		.140-01		.150-01		.140-01
BARIUM	*	.000	*	.000	*	.000
BERYLLIUM	*	.000	*	.000	*	.000
BISMUTH	*	.000	*	.000	*	.000
BORON	*	.000	*	.000	*	.000
CADMIUM	*	.000	*	.000	*	.000
CHROMIUM	*	.000	*	.000	*	.000
COBALT	*	.000	*	.000	*	.000
COPPER	*	.000	*	.000	*	.000
IRON	*	.000	*	.000	*	.000
LEAD	*	.000	*	.000	*	.000
MANGANESE	*	.000	*	.000	*	.000
MERCURY	<	.200	<	.200	<	.300
MOLYBDENUM	*	.000	*	.000	*	.000
NICKEL	*	.000	*	.000	*	.000
SELENIUM	*	.000	*	.000	*	.000
TELLURIUM	*	.000	*	.000	*	.000
THALLIUM	*	.000	*	.000	*	.000
TIN	*	.000	*	.000	*	.000
TITANIUM	*	.000	*	.000	*	.000
URANIUM	*	.000	*	.000	*	.000
VANADIUM	*	.000	*	.000	*	.000
ZINC	*	.000	*	.000	*	.000
ZIRCONIUM	*	.000	*	.000	*	.000

APPENDIX D
TRACE ELEMENT FLOWRATES

NOMENCLATURE

DSCM	Dry Standard Cubic Meter
G	Gram
J	Joule
MCG	Microgram
PPM	Parts per million by weight
SEC	Second
>	Less than
*	Sample not analyzed for the particular element/or ionic specie
N	Sample not analyzed
-	Concentration in the sample is less than the concentration in the blank

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APPENDIX D-1

TRACE ELEMENT FLOWRATES (g/sec)

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - COAL INLET

TRACE ELEMENT	TEST CONDITION					
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY	<	.943-02	<	.925-02	<	.953-02
ARSENIC		.802-01		.416-01		.429-01
BARIUM		4.39		2.77		3.62
BERYLLIUM		.660-01		.555-01		.572-01
BISMUTH	<	.142	<	.925-01	<	.953-01
BORON	*	.000	*	.000	*	.000
CADMIUM	<	.472-02	<	.462-02	<	.477-02
CHROMIUM		1.04		.786		.763
COBALT		.217		.162		.219
COPPER		.519		.509		.467
IRON		.108+04		.120+04		858.
LEAD		.849	<	.277	<	.238
MANGANESE		3.44		3.38		2.48
MERCURY		.330-02		.786-02		.524-02
MOLYBDENUM		.410		.601		.386
NICKEL		1.08		.832		.572
SELENIUM		.613-01		.462-01		.572-01
TELLURIUM	<	.943-02	<	.925-02	<	.953-02
THALLIUM	<	.189	<	.139	<	.143
TIN		.104		.832-01		3.00
TITANIUM		78.3		47.6		62.9
URANIUM	*	.000	*	.000	*	.000
VANADIUM		1.79		2.77		1.48
ZINC		2.31		2.36		2.05
ZIRCONIUM	*	.000	*	.000	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - BOTTOM ASH

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .126-02	< .864-03	< .130-02
ARSENIC	< .632-02	< .115-01	< .650-02
BARIUM	.569	1.11	.347
BERYLLIUM	.190-01	.935-02	.167-01
BISMUTH	< .126-01	.331	< .130-01
BORON	< .211-03	.288-03	.434-03
CADMIUM	< .632-04	.691-03	< .650-04
CHROMIUM	.158	.144	.160
COBALT	.105-01	< .144-03	.434-02
COPPER	.126	.331-01	.115
IRON	86.3	273.	93.2
LEAD	.716-01	.331-01	.455-01
MANGANESE	1.87	1.58	2.10
MERCURY	< .126-02	< .864-03	< .152-02
MOLYBDENUM	< .126-01	< .432-02	< .130-02
NICKEL	.114	.691-01	.115
SELENIUM	.147-02	.144-02	.542-02
TELLURIUM	< .190-02	.576-03	< .195-02
THALLIUM	< .842	< .576	< .867
TIN	< .421-02	< .576-02	< .434-02
TITANIUM	5.05	7.34	4.99
URANIUM	* .000	* .000	* .000
VANADIUM	.505	.489	.477
ZINC	.316	.446	.412
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP INLET
10 MICRON CYCLONE

TRACE ELEMENT		TEST CONDITION	
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.380-02	< .545-03	< .673-03
ARSENIC	.532-01	.509-01	.584-01
BARIUM	2.66	1.000	3.59
BERYLLIUM	.190-01	.236-01	.224-01
BISMUTH	< .570-02	.981	< .673-02
BORON	.931	.818	.830
CADMIUM	.551-02	.418-02	.494-02
CHROMIUM	.760	.291	.561
COBALT	.665-01	.891-01	.988-01
COPPER	.144	.109	.164
IRON	41.8	254.	71.8
LEAD	.148	1.82	.186
MANGANESE	1.58	1.34	1.59
MERCURY	< .950-03	.727-03	< .898-03
MOLYBDENUM	.247-01	.363-02	.157-01
NICKEL	.532	.145	.426
SELENIUM	.342-02	.164-02	.382-02
TELLURIUM	< .114-02	.109-02	< .135-02
THALLIUM	< .760	< .727	< .898
TIN	< .190-02	< .363-02	< .224-02
TITANIUM	8.36	7.63	9.65
URANIUM	* .000	* .000	* .000
VANADIUM	.418	.781	.471
ZINC	.969	.436	.763
ZIRCONIUM	* .000	* .000	* .000
ANION			
CHLORIDE	* .000	* .000	.786-01
FLUORIDE	* .000	* .000	.651-02
CYANIDE	* .000	* .000	< .224-03
NITRATE	* .000	* .000	.191-01
SULFATE	* .000	* .000	.583
AMMONIUM	* .000	* .000	.200-01

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP INLET
3 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION					
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY		.239-02	<	.667-03		.316-02
ARSENIC		.191		.174		.106
BARIUM		5.84		1.47		3.99
BERYLLIUM		.345-01		.356-01		.200-01
BISMUTH	<	.797-02		.756	<	.499-02
BORON		1.81		.957		.516
CADMIUM		.130-01		.356-02		.815-02
CHROMIUM		.425		.445		.299
COBALT		.877-01		.129		.682-01
COPPER		.215		.167		.138
IRON		55.8		245.		36.6
LEAD		.345		.400		.266
MANGANESE		1.97		1.69		1.56
MERCURY	<	.106-02	<	.111-02	<	.665-03
MOLYBDENUM		.266-01		.133-01		.133-01
NICKEL		.319		.222		.200
SELENIUM		.345-02	<	.222-03		.898-02
TELLURIUM	<	.159-02		.445-03	<	.998-03
THALLIUM	<	1.06	<	.890	<	.665
TIN	<	.266-02	<	.445-02		.333-02
TITANIUM		12.2		10.7		6.82
URANIUM	*	.000	*	.000	*	.000
VANADIUM		.824		1.38		.432
ZINC		1.67		.890		1.83
ZIRCONIUM	*	.000	*	.000	*	.000
ANION						
CHLORIDE	*	.000	*	.000		.386-01
FLUORIDE	*	.000	*	.000		.299-02
CYANIDE	*	.000	*	.000		.166-03
NITRATE	*	.000	*	.000	<	.233-02
SULFATE	*	.000	*	.000		.472-02
AMMONIUM	*	.000	*	.000		.499-03

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP INLET
1 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.118-01	< .213-03	.288-02
ARSENIC	.110	.107	.734-01
BARIUM	1.61	1.85	1.71
BERYLLIUM	.135-01	.107-01	.979-02
BISMUTH	< .254-02	.277-01	< .184-02
BORON	.279	.249	.239
CADMIUM	.118-01	.391-02	.612-02
CHROMIUM	.254	.192	.147
COBALT	.516-01	.483-01	.300-01
COPPER	.101	.490-01	.673-01
IRON	17.7	92.3	14.7
LEAD	.186	.206	.153
MANGANESE	.820	.547	.734
MERCURY	< .338-03	< .284-03	< .245-03
MOLYBDENUM	.118-01	.426-02	.673-02
NICKEL	.127	.994-01	.918-01
SELENIUM	.127-02	< .710-04	.153-02
TELLURIUM	< .507-03	.213-03	< .367-03
THALLIUM	< .338	< .284	< .245
TIN	.338-02	.213-02	.612-02
TITANIUM	5.58	4.76	4.10
URANIUM	* .000	* .000	* .000
VANADIUM	.406	.639	.233
ZINC	1.01	.568	.673
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP INLET FILTER

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.826-01	.121-01	.509-01
ARSENIC	.620-01	.144	.228-01
BARIUM	.201	.769-01	.737-01
BERYLLIUM	.387-02	.365-02	.214-02
BISMUTH	< .516-03	.346-01	< .268-03
BORON	* .000	* .000	* .000
CADMIUM	.145-01	.596-02	.791-02
CHROMIUM	.645-01	.231-01	.228-01
COBALT	.516-02	.183-01	.375-02
COPPER	.214-01	.288-01	.109-01
IRON	2.58	13.3	2.14
LEAD	.207-01	.308-01	.129-01
MANGANESE	.108	.634-01	.335-04
MERCURY	< .155-03	< .115-03	< .804-04
MOLYBDENUM	.127	.981-01	.683-01
NICKEL	.516-01	.133-01	.697-02
SELENIUM	.258-02	.711-03	.241-02
TELLURIUM	.981-03	.634-03	.630-03
THALLIUM	.310-02	.731-02	.134-02
TIN	.258-02	< .192-02	.804-02
TITANIUM	.361	.731	.308
URANIUM	* .000	* .000	* .000
VANADIUM	.284	.385	.131
ZINC	.139	.211	.241
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP INLET
XAD-2 RESIN

TRACE ELEMENT		TEST CONDITION				
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY	<	.193-02	*	.000	<	.104-02
ARSENIC	<	.231-02	*	.000	<	.104-02
BARIUM		.964-01	*	.000		.271
BERYLLIUM	<	.193-02	*	.000	<	.104-02
BISMUTH	<	.154-02	*	.000	<	.626-03
BORON		.150	*	.000	<	.418-01
CADMIUM	<	.771-04	*	.000		.188-03
CHROMIUM		.540-01	*	.000		.117-01
COBALT	<	.771-01	*	.000		.376-01
COPPER	<	.154-03	*	.000		.376-02
IRON		.147-01	*	.000		.480
LEAD		.540-02	*	.000		.292-02
MANGANESE		.656-02	*	.000		.710-03
MERCURY	<	.270-02	*	.000	<	.125-02
MOLYBDENUM	<	.347-01	*	.000	<	.146-01
NICKEL	<	.270-01	*	.000	<	.125-01
SELENIUM	<	.116-02	*	.000		.835-03
TELLURIUM	<	.270-02	*	.000	<	.146-02
THALLIUM		.208-01	*	.000		.981-02
TIN	<	.154-02	*	.000	<	.626-03
TITANIUM	<	.154-01	*	.000	<	.835-02
URANIUM	*	.000	*	.000	*	.000
VANADIUM	<	.347-01	*	.000	<	.167-01
ZINC	<	.116-01	*	.000	<	.626-02
ZIRCONIUM	*	.000	*	.000	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP INLET
FIRST IMPINGER

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .103-03	* .000	< .802-04
ARSENIC	.165-02	* .000	.108-02
BARIUM	< .257-01	* .000	.441-01
BERYLLIUM	< .103-03	* .000	.201-04
BISMUTH	.154-03	* .000	.229-03
BORON	1.49	* .000	1.20
CADMIUM	< .360-05	* .000	.193-03
CHROMIUM	2.47	* .000	.156
COBALT	.278-01	* .000	.152-01
COPPER	.514-01	* .000	.285-01
IRON	.298	* .000	2.29
LEAD	.113-02	* .000	.842
MANGANESE	.257	* .000	.168
MERCURY	.154-02	* .000	< .401-03
MOLYBDENUM	.175	* .000	.923-01
NICKEL	1.49	* .000	.441-01
SELENIUM	.309-01	* .000	.269-01
TELLURIUM	< .257-03	* .000	< .160-03
THALLIUM	.617-03	* .000	.345-03
TIN	.386-02	* .000	< .401-03
TITANIUM	< .514	* .000	< .401
URANIUM	* .000	* .000	* .000
VANADIUM	.453-02	* .000	.521-02
ZINC	.149	* .000	.923-01
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP INLET
2ND & 3RD IMPINGERS

TRACE ELEMENT				TEST CONDITION		
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY	<	.166-03	*	.000	<	.871-04
ARSENIC	<	.276-03	*	.000		.348-03
BARIUM	*	.000	*	.000	*	.000
BERYLLIUM	*	.000	*	.000	*	.000
BISMUTH	*	.000	*	.000	*	.000
BORON	*	.000	*	.000	*	.000
CADMIUM	*	.000	*	.000	*	.000
CHROMIUM	*	.000	*	.000	*	.000
COBALT	*	.000	*	.000	*	.000
COPPER	*	.000	*	.000	*	.000
IRON	*	.000	*	.000	*	.000
LEAD	*	.000	*	.000	*	.000
MANGANESE	*	.000	*	.000	*	.000
MERCURY	<	.332-03	*	.000	<	.871-02
MOLYBDENUM	*	.000	*	.000	*	.000
NICKEL	*	.000	*	.000	*	.000
SELENIUM	*	.000	*	.000	*	.000
TELLURIUM	*	.000	*	.000	*	.000
THALLIUM	*	.000	*	.000	*	.000
TIN	*	.000	*	.000	*	.000
TITANIUM	*	.000	*	.000	*	.000
URANIUM	*	.000	*	.000	*	.000
VANADIUM	*	.000	*	.000	*	.000
ZINC	*	.000	*	.000	*	.000
ZIRCONIUM	*	.000	*	.000	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP INLET

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.103	< .135-01	< .588-01
ARSENIC	.421	.475	.263
BARIUM	10.4	4.39	9.69
BERYLLIUM	.730-01	.735-01	.554-01
BISMUTH	< .184-01	1.80	< .147-01
BORON	4.66	2.02	2.83
CADMIUM	.449-01	.176-01	.275-01
CHROMIUM	4.03	.951	1.20
COBALT	.316	.285	.254
COPPER	.534	.354	.412
IRON	118.	605.	128.
LEAD	.707	2.45	1.46
MANGANESE	4.74	3.65	4.06
MERCURY	< .708-02	.224-02	< .123-01
MOLYBDENUM	.399	.119	.211
NICKEL	2.55	.481	.781
SELENIUM	.428-01	.264-02	.444-01
TELLURIUM	< .718-02	.238-02	< .496-02
THALLIUM	< 2.19	< 1.91	< 1.82
TIN	< .159-01	< .121-01	< .208-01
TITANIUM	27.1	23.8	21.3
URANIUM	* .000	* .000	* .000
VANADIUM	1.97	3.18	1.29
ZINC	3.96	2.11	3.61
ZIRCONIUM	* .000	* .000	* .000
ANION			
CHLORIDE	* .000	* .000	.117
FLUORIDE	* .000	* .000	.950-02
CYANIDE	* .000	* .000	< .391-03
NITRATE	* .000	* .000	.214-01
SULFATE	* .000	* .000	.588
AMMONIUM	* .000	* .000	.205-01

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP HOPPER ASH

TRACE ELEMENT	TEST CONDITION BASELINE		BOOS1		BOOS2
CATION					
ANTIMONY	< .256-02	<	.271-02	<	.212-02
ARSENIC	< .154-01		.776-01	<	.127-01
BARIUM	.973		4.65		.250
BERYLLIUM	.379-01		.349-01		.276-01
BISMUTH	< .307-01		2.21		.297-01
BORON	1.90		1.51		1.65
CADMIUM	.210-01		.620-02		.594-02
CHROMIUM	.666		.465		.466
COBALT	< .102-01		.302	<	.848-02
COPPER	.246		.163		.191
IRON	169.		620.		119.
LEAD	.318		.233		.288
MANGANESE	6.15		4.65		2.54
MERCURY	< .410-02	<	.271-02		.382-02
MOLYBDENUM	< .307-01	<	.116-01		.102
NICKEL	.768		.178		.377
SELENIUM	.512-02		.388-02		.119-01
TELLURIUM	< .461-02	<	.776-03	<	.382-02
THALLIUM	< 2.05	<	1.55	<	1.70
TIN	.154-01	<	.194-01	<	.848-02
TITANIUM	20.5		20.9		11.0
URANIUM	* .000	*	.000	*	.000
VANADIUM	1.18		1.40		.890
ZINC	1.08		1.01		.636
ZIRCONIUM	.871		.543	*	.000
ANION					
CHLORIDE	.118		.113	<	.220-01
FLUORIDE	.517-01		.109-01		.848-02
CYANIDE	< .512-03	<	.388-03	<	.424-03
NITRATE	.717-01		.217-01		.184
SULFATE	1.00		1.02		.900
AMMONIUM	.118-01		.225-01		.229-01

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP OUTLET
10 MICRON CYCLONE

TRACE ELEMENT		TEST CONDITION				
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY		.248-03		.106-03	<	.630-04
ARSENIC		.294-02		.264-02		.193-02
BARIUM		.712		.227		.462
BERYLLIUM		.310-02		.264-02		.170-02
BISMUTH	<	.929-03		.633-02	<	.630-03
BORON		.898-01		.449-01		.378-01
CADMIUM		.774-03		.256-03		.294-03
CHROMIUM		.371-01		.317-01		.231-01
COBALT		.108-01		.449-02		.862-02
COPPER		.210-01		.119-01		.191-01
IRON		4.95		58.1		6.93
LEAD		.142-01		.897-02		.967-02
MANGANESE		.272		.211		.168
MERCURY	<	.124-03		.132-03		.840-04
MOLYBDENUM		.155-02		.528-03		.840-03
NICKEL		.303-01		.290-01		.183-01
SELENIUM		.248-03	<	.264-04		.357-03
TELLURIUM	<	.186-03	<	.264-04	<	.126-03
THALLIUM	<	.124	<	.106	<	.840-01
TIN		.310-03	<	.528-03	<	.210-03
TITANIUM		1.18		.818		1.03
URANIUM	*	.000	*	.000	*	.000
VANADIUM		.650-01		.108		.399-01
ZINC		.867-01		.396-01		.651-01
ZIRCONIUM	*	.000	*	.000	*	.000
ANION						
CHLORIDE		.721-02		.115-01	*	.000
FLUORIDE		.743-03		.765-03	*	.000
CYANIDE	<	.310-04	<	.264-04	*	.000
NITRATE		.217-02		.694-02	*	.000
SULFATE		.732-01		.648-01	*	.000
AMMONIUM		.152-02		.369-03	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP OUTLET
3 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.707-03	< .345-04	.772-04
ARSENIC	.108-01	.851-02	.864-02
BARIUM	.253	.113	.309
BERYLLIUM	.236-02	.161-02	.185-02
BISMUTH	< .505-03	.598-01	< .463-03
BORON	.690-01	.540-01	.586-01
CADMIUM	.976-03	.207-03	.556-03
CHROMIUM	.303-01	.207-01	.185-01
COBALT	.724-02	.448-02	.633-02
COPPER	.153-01	.851-02	.140-01
IRON	3.87	13.8	3.70
LEAD	.219-01	.161-01	.201-01
MANGANESE	.125	.839-01	.110
MERCURY	< .673-04	< .460-04	< .617-04
MOLYBDENUM	< .505-03	.345-03	.123-02
NICKEL	.202-01	.126-01	.170-01
SELENIUM	.219-03	.690-04	.170-03
TELLURIUM	< .101-03	.460-04	< .926-04
THALLIUM	< .673-01	< .460-01	< .617-01
TIN	.505-04	< .230-03	.154-03
TITANIUM	.993-01	.632	.756
URANIUM	* .000	* .000	* .000
VANADIUM	.522-01	.563-01	.401-01
ZINC	.114	.368-01	.926-01
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP OUTLET
1 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.994-03	.257-04	.478-03
ARSENIC	.877-02	.770-02	.478-02
BARIUM	.117	.144	.154
BERYLLIUM	.105-02	.108-02	.515-03
BISMUTH	< .175-03	.293-01	< .221-03
BORON	* .000	.770-02	.136-01
CADMIUM	.818-03	.262-03	.405-03
CHROMIUM	.164-01	.134-01	.920-02
COBALT	.286-02	.308-02	.136-02
COPPER	.702-02	.416-02	.405-02
IRON	1.40	6.16	.736
LEAD	.134-01	.134-01	.920-02
MANGANESE	.643-01	.395-01	.221-01
MERCURY	< .234-04	< .205-04	< .257-04
MOLYBDENUM	.105-02	.308-03	.772-03
NICKEL	.877-02	.719-02	.515-02
SELENIUM	< .117-04	.205-04	< .147-04
TELLURIUM	< .351-04	.257-04	< .331-04
THALLIUM	< .234-01	< .205-01	< .147-01
TIN	.175-03	< .103-03	.993-03
TITANIUM	.333	.282	.191
URANIUM	* .000	* .000	* .000
VANADIUM	.327-01	.452-01	.162-01
ZINC	.643-01	.411-01	.552-01
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP OUTLET FILTER

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.270-02	.365-03	.407-02
ARSENIC	.211-02	.489-02	.488-02
BARIUM	.231-02	.276-02	.132-01
BERYLLIUM	.112-03	.107-03	.179-03
BISMUTH	< .198-04	.631-03	< .326-04
BORON	* .000	* .000	* .000
CADMIUM	.593-03	.213-03	.667-03
CHROMIUM	.152-02	.107-02	.488-02
COBALT	< .198-04	.365-03	.505-03
COPPER	.857-03	.498-04	.195-02
IRON	.158	.373	.326
LEAD	.435-02	.854-03	.179-02
MANGANESE	.356-05	.213-02	.732-02
MERCURY	< .395-05	.800-05	< .977-05
MOLYBDENUM	.376-02	.311-02	.651-02
NICKEL	.112-02	.498-03	.179-02
SELENIUM	.105-03	.240-04	.293-03
TELLURIUM	.185-04	.889-05	.521-04
THALLIUM	.138-03	.240-03	.133-03
TIN	< .461-04	< .889-04	.326-03
TITANIUM	.923-02	.178-01	.439-01
URANIUM	* .000	* .000	* .000
VANADIUM	.791-02	.124-01	.116-01
ZINC	.356-02	.640-02	.163-01
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP OUTLET
XAD-2 RESIN

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .930-03	.213-02	< .759-03
ARSENIC	< .116-02	< .583-02	< .949-03
BARIUM	.256	.437-01	.646-01
BERYLLIUM	< .697-03	< .874-03	< .759-03
BISMUTH	< .697-03	< .146-02	.146-02
BORON	.628-01	.437	< .190-01
CADMIUM	< .465-04	.283-02	.570-04
CHROMIUM	.163-01	.641-01	.165-01
COBALT	< .465-01	< .146-01	< .380-01
COPPER	.325-02	< .233-03	< .190-02
IRON	.837-02	1.05	.120-01
LEAD	< .697-04	< .583-03	< .570-04
MANGANESE	.279-03	.221-01	.816-03
MERCURY	< .116-02	< .204-02	< .949-03
MOLYBDENUM	< .139-01	< .146-01	< .114-01
NICKEL	< .116-01	< .583-03	< .949-02
SELENIUM	.216-01	.128-01	.103-01
TELLURIUM	< .163-02	< .583-03	< .133-02
THALLIUM	.128-01	< .175-02	.101-01
TIN	.325-02	< .233-02	.114-02
TITANIUM	< .697-02	.437	< .570-02
URANIUM	* .000	* .000	* .000
VANADIUM	< .139-02	< .117-02	< .949-02
ZINC	< .697-02	< .175-01	< .759-02
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP OUTLET
FIRST IMPINGER

TRACE ELEMENT		TEST CONDITION	
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .687-04	< .129-03	< .754-04
ARSENIC	.113-02	.180-02	.117-02
BARIUM	< .172-01	.729-01	.415-01
BERYLLIUM	< .687-04	< .429-04	.151-04
BISMUTH	< .687-04	< .129-03	.113-03
BORON	.962	1.11	1.06
CADMIUM	.155-03	.137-02	< .377-05
CHROMIUM	1.79	3.82	.128
COBALT	.240-01	.382-01	.943-02
COPPER	.515-02	.257-04	.226-02
IRON	1.99	14.2	1.58
LEAD	.199-03	< .429-04	< .754-05
MANGANESE	.220	.120	.830-01
MERCURY	.687-03	< .858-02	< .377-03
MOLYBDENUM	.127	.287-01	.121-01
NICKEL	.756	1.67	.528
SELENIUM	.189-01	.176-01	.223-01
TELLURIUM	< .172-03	.172-03	.377-03
THALLIUM	.447-03	< .858-04	.241-03
TIN	.687-03	< .129-02	.754-03
TITANIUM	< .343	< .429-03	< .377
URANIUM	* .000	* .000	* .000
VANADIUM	.687-03	.472-02	.260-02
ZINC	< .343-01	.472-02	< .377-01
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP OUTLET
2ND & 3RD IMPINGERS

TRACE ELEMENT		TEST CONDITION				
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY		.102-03	<	.126-03	<	.825-04
ARSENIC		.475-03		.629-03		.385-03
BARIUM	*	.000	*	.000	*	.000
BERYLLIUM	*	.000	*	.000	*	.000
BISMUTH	*	.000	*	.000	*	.000
BORON	*	.000	*	.000	*	.000
CADMIUM	*	.000	*	.000	*	.000
CHROMIUM	*	.000	*	.000	*	.000
COBALT	*	.000	*	.000	*	.000
COPPER	*	.000	*	.000	*	.000
IRON	*	.000	*	.000	*	.000
LEAD	*	.000	*	.000	*	.000
MANGANESE	*	.000	*	.000	*	.000
MERCURY	<	.679-02	<	.839-02	<	.825-02
MOLYBDENUM	*	.000	*	.000	*	.000
NICKEL	*	.000	*	.000	*	.000
SELENIUM	*	.000	*	.000	*	.000
TELLURIUM	*	.000	*	.000	*	.000
THALLIUM	*	.000	*	.000	*	.000
TIN	*	.000	*	.000	*	.000
TITANIUM	*	.000	*	.000	*	.000
URANIUM	*	.000	*	.000	*	.000
VANADIUM	*	.000	*	.000	*	.000
ZINC	*	.000	*	.000	*	.000
ZIRCONIUM	*	.000	*	.000	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - G/SEC - ESP OUTLET

TRACE ELEMENT	TEST CONDITION		
	BASELINE	BOOS1	BOOS2
CATION			
ANTIMONY	.575-02	.291-02	< .561-02
ARSENIC	.274-01	.320-01	.227-01
BARIUM	1.36	.603	1.04
BERYLLIUM	.738-02	.635-02	.502-02
BISMUTH	< .239-02	.976-01	< .292-02
BORON	1.18	1.66	1.19
CADMIUM	.336-02	.514-02	.198-02
CHROMIUM	1.89	3.95	.200
COBALT	.915-01	.651-01	.642-01
COPPER	.526-01	.248-01	.435-01
IRON	12.4	93.6	13.3
LEAD	.542-01	.399-01	.408-01
MANGANESE	.681	.479	.391
MERCURY	< .886-02	.192-01	.976-02
MOLYBDENUM	.148	.476-01	.328-01
NICKEL	.828	1.72	.580
SELENIUM	.411-01	< .305-01	.335-01
TELLURIUM	< .214-02	< .861-03	< .201-02
THALLIUM	< .228	< .174	< .171
TIN	.452-02	< .457-02	< .358-02
TITANIUM	1.97	2.19	2.40
URANIUM	* .000	* .000	* .000
VANADIUM	.160	.228	.120
ZINC	.310	.146	.274
ZIRCONIUM	* .000	* .000	* .000
ANION			
CHLORIDE	.721-02	.115-01	* .000
FLUORIDE	.743-03	.765-03	* .000
CYANIDE	< .310-04	< .264-04	* .000
NITRATE	.217-02	.694-02	* .000
SULFATE	.732-01	.648-01	* .000
AMMONIUM	.152-02	.369-03	* .000

APPENDIX D-2

TRACE ELEMENT FLOWRATE (μg/J)

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - COAL INLET

TRACE ELEMENT		TEST CONDITION				
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY	<	.798-05	<	.763-05	<	.778-05
ARSENIC		.678-04		.343-04		.350-04
BARIUM		.371-02		.229-02		.296-02
BERYLLIUM		.558-04		.458-04		.467-04
BISMUTH	<	.120-03	<	.763-04	<	.778-04
BORON	*	.000	*	.000	*	.000
CADMIUM	<	.399-05	<	.381-05	<	.389-05
CHROMIUM		.878-03		.648-03		.623-03
COBALT		.183-03		.133-03		.179-03
COPPER		.439-03		.420-03		.381-03
IRON		.917		.992		.700
LEAD		.718-03	<	.229-03	<	.195-03
MANGANESE		.291-02		.278-02		.202-02
MERCURY		.279-05		.648-05		.428-05
MOLYBDENUM		.347-03		.496-03		.315-03
NICKEL		.917-03		.686-03		.467-03
SELENIUM		.519-04		.381-04		.467-04
TELLURIUM	<	.798-05	<	.763-05	<	.778-05
THALLIUM	<	.160-03	<	.114-03	<	.117-03
TIN		.878-04		.686-04		.245-02
TITANIUM		.662-01		.393-01		.514-01
URANIUM	*	.000	*	.000	*	.000
VANADIUM		.152-02		.229-02		.121-02
ZINC		.195-02		.195-02		.167-02
ZIRCONIUM	*	.000	*	.000	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - BOTTOM ASH

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .107-05	< .712-06	< .106-05
ARSENIC	< .534-05	< .950-05	< .531-05
BARIUM	.481-03	.914-03	.283-03
BERYLLIUM	.160-04	.772-05	.136-04
BISMUTH	< .107-04	.273-03	< .106-04
BORON	< .178-06	.237-06	.354-06
CADMIUM	< .534-07	.570-06	< .531-07
CHROMIUM	.134-03	.119-03	.131-03
COBALT	.890-05	< .119-06	.354-05
COPPER	.107-03	.273-04	.938-04
IRON	.730-01	.226	.761-01
LEAD	.605-04	.273-04	.372-04
MANGANESE	.158-02	.131-02	.172-02
MERCURY	< .107-05	< .712-06	< .124-05
MOLYBDENUM	< .107-04	< .356-05	< .106-05
NICKEL	.962-04	.570-04	.938-04
SELENIUM	.125-05	.119-05	.443-05
TELLURIUM	< .160-05	.475-06	< .159-05
THALLIUM	< .712-03	< .475-03	< .708-03
TIN	< .356-05	< .475-05	< .354-05
TITANIUM	.427-02	.605-02	.407-02
URANIUM	* .000	* .000	* .000
VANADIUM	.427-03	.404-03	.389-03
ZINC	.267-03	.368-03	.336-03
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP INLET
10 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.322-05	< .450-06	< .550-06
ARSENIC	.450-04	.420-04	.477-04
BARIUM	.225-02	.825-03	.293-02
BERYLLIUM	.161-04	.195-04	.183-04
BISMUTH	< .483-05	.810-03	< .550-05
BORON	.788-03	.675-03	.679-03
CADMIUM	.466-05	.345-05	.404-05
CHROMIUM	.643-03	.240-03	.459-03
COBALT	.563-04	.735-04	.807-04
COPPER	.122-03	.900-04	.134-03
IRON	.354-01	.210	.587-01
LEAD	.125-03	.150-02	.152-03
MANGANESE	.134-02	.111-02	.130-02
MERCURY	< .804-06	.600-06	< .734-06
MOLYBDENUM	.209-04	.300-05	.128-04
NICKEL	.450-03	.120-03	.349-03
SELENIUM	.290-05	.135-05	.312-05
TELLURIUM	< .965-06	.900-06	< .110-05
THALLIUM	< .643-03	< .600-03	< .734-03
TIN	< .161-05	< .300-05	< .183-05
TITANIUM	.708-02	.630-02	.789-02
URANIUM	* .000	* .000	* .000
VANADIUM	.354-03	.645-03	.385-03
ZINC	.820-03	.360-03	.624-03
ZIRCONIUM	* .000	* .000	* .000
ANION			
CHLORIDE	* .000	* .000	.642-04
FLUORIDE	* .000	* .000	.532-05
CYANIDE	* .000	* .000	< .183-06
NITRATE	* .000	* .000	.156-04
SULFATE	* .000	* .000	.476-03
AMMONIUM	* .000	* .000	.163-04

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP INLET
3 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.202-05	< .551-06	.258-05
ARSENIC	.162-03	.143-03	.870-04
BARIUM	.495-02	.121-02	.326-02
BERYLLIUM	.292-04	.294-04	.165-04
BISMUTH	< .675-05	.624-03	< .408-05
BORON	.153-02	.790-03	.421-03
CADMIUM	.110-04	.294-05	.666-05
CHROMIUM	.360-03	.367-03	.245-03
COBALT	.742-04	.107-03	.557-04
COPPER	.182-03	.138-03	.113-03
IRON	.472-01	.202	.299-01
LEAD	.292-03	.331-03	.217-03
MANGANESE	.166-02	.140-02	.128-02
MERCURY	< .899-06	< .918-06	< .544-06
MOLYBDENUM	.225-04	.110-04	.109-04
NICKEL	.270-03	.184-03	.163-03
SELENIUM	.292-05	< .184-06	.734-05
TELLURIUM	< .135-05	.367-06	< .816-06
THALLIUM	< .899-03	< .735-03	< .544-03
TIN	< .225-05	< .367-05	.272-05
TITANIUM	.103-01	.882-02	.557-02
URANIUM	* .000	* .000	* .000
VANADIUM	.697-03	.114-02	.353-03
ZINC	.142-02	.735-03	.150-02
ZIRCONIUM	* .000	* .000	* .000
ANION			
CHLORIDE	* .000	* .000	.315-04
FLUORIDE	* .000	* .000	.245-05
CYANIDE	* .000	* .000	< .136-06
NITRATE	* .000	* .000	.190-05
SULFATE	* .000	* .000	.386-05
AMMONIUM	* .000	* .000	.408-06

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP INLET
1 MICRON CYCLONE

TRACE ELEMENT CATION	TEST CONDITION BASELINE	 BOOS1	 BOOS2
ANTIMONY	.100-04	< .176-06	.235-05
ARSENIC	.930-04	.879-04	.600-04
BARIUM	.136-02	.152-02	.140-02
BERYLLIUM	.114-04	.879-05	.800-05
BISMUTH	< .215-05	.229-04	< .150-05
BORON	.236-03	.205-03	.195-03
CADMIUM	.100-04	.322-05	.500-05
CHROMIUM	.215-03	.158-03	.120-03
COBALT	.436-04	.399-04	.245-04
COPPER	.858-04	.405-04	.550-04
IRON	.150-01	.762-01	.120-01
LEAD	.157-03	.170-03	.125-03
MANGANESE	.694-03	.451-03	.600-03
MERCURY	< .286-06	< .235-06	< .200-06
MOLYBDENUM	.100-04	.352-05	.550-05
NICKEL	.107-03	.821-04	.750-04
SELENIUM	.107-05	< .586-07	.125-05
TELLURIUM	< .429-06	.176-06	< .300-06
THALLIUM	< .286-03	< .235-03	< .200-03
TIN	.286-05	.176-05	.500-05
TITANIUM	.472-02	.393-02	.335-02
URANIUM	* .000	* .000	* .000
VANADIUM	.343-03	.528-03	.190-03
ZINC	.858-03	.469-03	.550-03
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP INLET FILTER

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.699-04	.100-04	.416-04
ARSENIC	.525-04	.119-03	.186-04
BARIUM	.170-03	.635-04	.602-04
BERYLLIUM	.328-05	.302-05	.175-05
BISMUTH	< .437-06	.286-04	< .219-06
BORON	* .000	* .000	* .000
CADMIUM	.122-04	.492-05	.646-05
CHROMIUM	.546-04	.190-04	.186-04
COBALT	.437-05	.151-04	.307-05
COPPER	.181-04	.238-04	.887-05
IRON	.219-02	.110-01	.175-02
LEAD	.175-04	.254-04	.105-04
MANGANESE	.918-04	.524-04	.274-07
MERCURY	< .131-06	< .952-07	< .657-07
MOLYBDENUM	.107-03	.810-04	.559-04
NICKEL	.437-04	.110-04	.570-05
SELENIUM	.219-05	.587-06	.197-05
TELLURIUM	.830-06	.524-06	.515-06
THALLIUM	.262-05	.603-05	.110-05
TIN	.219-05	< .159-05	.657-05
TITANIUM	.306-03	.603-03	.252-03
URANIUM	* .000	* .000	* .000
VANADIUM	.240-03	.317-03	.107-03
ZINC	.118-03	.175-03	.197-03
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP INLET
XAD-2 RESIN

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .163-05	* .000	< .853-06
ARSENIC	< .196-05	* .000	< .853-06
BARIUM	.816-04	* .000	.222-03
BERYLLIUM	< .163-05	* .000	< .853-06
BISMUTH	< .131-05	* .000	< .512-06
BORON	.127-03	* .000	< .341-04
CADMIUM	< .653-07	* .000	.154-06
CHROMIUM	.457-04	* .000	.955-05
COBALT	< .653-04	* .000	.307-04
COPPER	< .131-06	* .000	.307-05
IRON	.124-04	* .000	.392-03
LEAD	.457-05	* .000	.239-05
MANGANESE	.555-05	* .000	.580-06
MERCURY	< .229-05	* .000	< .102-05
MOLYBDENUM	< .294-04	* .000	< .119-04
NICKEL	< .229-04	* .000	< .102-04
SELENIUM	< .979-06	* .000	.682-06
TELLURIUM	< .229-05	* .000	< .119-05
THALLIUM	.176-04	* .000	.802-05
TIN	< .131-05	* .000	< .512-06
TITANIUM	< .131-04	* .000	< .682-05
URANIUM	* .000	* .000	* .000
VANADIUM	< .294-04	* .000	< .136-04
ZINC	< .979-05	* .000	< .512-05
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP INLET
FIRST IMPINGER

TRACE ELEMENT	TEST CONDITION					
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY	<	.871-07	*	.000	<	.656-07
ARSENIC		.139-05	*	.000		.885-06
BARIUM	<	.218-04	*	.000		.361-04
BERYLLIUM	<	.871-07	*	.000		.164-07
BISMUTH		.131-06	*	.000		.187-06
BORON		.126-02	*	.000		.983-03
CADMIUM	<	.305-08	*	.000		.157-06
CHROMIUM		.209-02	*	.000		.128-03
COBALT		.235-04	*	.000		.125-04
COPPER		.436-04	*	.000		.233-04
IRON		.253-03	*	.000		.187-02
LEAD		.958-06	*	.000		.688-03
MANGANESE		.218-03	*	.000		.138-03
MERCURY		.131-05	*	.000	<	.328-06
MOLYBDENUM		.148-03	*	.000		.754-04
NICKEL		.126-02	*	.000		.361-04
SELENIUM		.261-04	*	.000		.220-04
TELLURIUM	<	.218-06	*	.000	<	.131-06
THALLIUM		.523-06	*	.000		.282-06
TIN		.327-05	*	.000	<	.328-06
TITANIUM	<	.436-03	*	.000	<	.328-03
URANIUM	*	.000	*	.000	*	.000
VANADIUM		.383-05	*	.000		.426-05
ZINC		.126-03	*	.000		.754-04
ZIRCONIUM	*	.000	*	.000	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP INLET
2ND & 3RD IMPINGERS

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .140-06	* .000	< .712-07
ARSENIC	< .234-06	* .000	.285-06
BARIUM	* .000	* .000	* .000
BERYLLIUM	* .000	* .000	* .000
BISMUTH	* .000	* .000	* .000
BORON	* .000	* .000	* .000
CADMIUM	* .000	* .000	* .000
CHROMIUM	* .000	* .000	* .000
COBALT	* .000	* .000	* .000
COPPER	* .000	* .000	* .000
IRON	* .000	* .000	* .000
LEAD	* .000	* .000	* .000
MANGANESE	* .000	* .000	* .000
MERCURY	< .281-06	* .000	< .712-05
MOLYBDENUM	* .000	* .000	* .000
NICKEL	* .000	* .000	* .000
SELENIUM	* .000	* .000	* .000
TELLURIUM	* .000	* .000	* .000
THALLIUM	* .000	* .000	* .000
TIN	* .000	* .000	* .000
TITANIUM	* .000	* .000	* .000
URANIUM	* .000	* .000	* .000
VANADIUM	* .000	* .000	* .000
ZINC	* .000	* .000	* .000
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP INLET

TRACE ELEMENT				TEST CONDITION		
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY		.871-04	<	.112-04	<	.481-04
ARSENIC		.356-03		.392-03		.215-03
BARIUM		.883-02		.363-02		.792-02
BERYLLIUM		.618-04		.607-04		.453-04
BISMUTH	<	.156-04		.149-02	<	.120-04
BORON		.394-02		.167-02		.231-02
CADMIUM		.380-04		.145-04		.225-04
CHROMIUM		.341-02		.785-03		.979-03
COBALT		.267-03		.235-03		.207-03
COPPER		.452-03		.292-03		.337-03
IRON		.100		.499		.105
LEAD		.598-03		.203-02		.120-02
MANGANESE		.401-02		.301-02		.332-02
MERCURY	<	.599-05		.185-05	<	.100-04
MOLYBDENUM		.338-03		.985-04		.172-03
NICKEL		.216-02		.397-03		.639-03
SELENIUM		.362-04		.218-05		.363-04
TELLURIUM	<	.608-05		.197-05	<	.406-05
THALLIUM	<	.185-02	<	.158-02	<	.149-02
TIN	<	.135-04	<	.100-04	<	.170-04
TITANIUM		.229-01		.196-01		.174-01
URANIUM	*	.000	*	.000	*	.000
VANADIUM		.167-02		.263-02		.105-02
ZINC		.335-02		.174-02		.295-02
ZIRCONIUM	*	.000	*	.000	*	.000
ANION						
CHLORIDE	*	.000	*	.000		.957-04
FLUORIDE	*	.000	*	.000		.777-05
CYANIDE	*	.000	*	.000	<	.319-06
NITRATE	*	.000	*	.000		.175-04
SULFATE	*	.000	*	.000		.480-03
AMMONIUM	*	.000	*	.000		.167-04

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP HOPPER ASH

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .217-05	< .224-05	< .173-05
ARSENIC	< .130-04	.640-04	< .104-04
BARIUM	.823-03	.384-02	.204-03
BERYLLIUM	.321-04	.288-04	.225-04
BISMUTH	< .260-04	.182-02	.242-04
BORON	.160-02	.125-02	.135-02
CADMIUM	.178-04	.512-05	.485-05
CHROMIUM	.563-03	.384-03	.381-03
COBALT	< .866-05	.249-03	< .692-05
COPPER	.208-03	.134-03	.156-03
IRON	.143	.512	.969-01
LEAD	.269-03	.192-03	.235-03
MANGANESE	.520-02	.384-02	.208-02
MERCURY	< .347-05	< .224-05	.312-05
MOLYBDENUM	< .260-04	< .960-05	.831-04
NICKEL	.650-03	.147-03	.308-03
SELENIUM	.433-05	.320-05	.969-05
TELLURIUM	< .390-05	< .640-06	< .312-05
THALLIUM	< .173-02	< .128-02	< .138-02
TIN	.130-04	< .160-04	< .692-05
TITANIUM	.173-01	.173-01	.900-02
URANIUM	* .000	* .000	* .000
VANADIUM	.996-03	.115-02	.727-03
ZINC	.910-03	.832-03	.519-03
ZIRCONIUM	.736-03	.448-03	* .000
ANION			
CHLORIDE	.996-04	.934-04	< .180-04
FLUORIDE	.437-04	.896-05	.692-05
CYANIDE	< .433-06	< .320-06	< .346-06
NITRATE	.606-04	.179-04	.151-03
SULFATE	.849-03	.841-03	.735-03
AMMONIUM	.996-05	.186-04	.187-04

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP OUTLET
10 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.210-06	.871-07	< .515-07
ARSENIC	.249-05	.218-05	.158-05
BARIUM	.603-03	.187-03	.378-03
BERYLLIUM	.262-05	.218-05	.139-05
BISMUTH	< .786-06	.523-05	< .515-06
BORON	.760-04	.370-04	.309-04
CADMIUM	.655-06	.211-06	.240-06
CHROMIUM	.314-04	.261-04	.189-04
COBALT	.917-05	.370-05	.704-05
COPPER	.178-04	.980-05	.156-04
IRON	.419-02	.479-01	.567-02
LEAD	.121-04	.741-05	.790-05
MANGANESE	.231-03	.174-03	.137-03
MERCURY	< .105-06	.109-06	.687-07
MOLYBDENUM	.131-05	.436-06	.687-06
NICKEL	.257-04	.240-04	.149-04
SELENIUM	.210-06	< .218-07	.292-06
TELLURIUM	< .157-06	< .218-07	< .103-06
THALLIUM	< .105-03	< .871-04	< .687-04
TIN	.262-06	< .436-06	< .172-06
TITANIUM	.996-03	.675-03	.841-03
URANIUM	* .000	* .000	* .000
VANADIUM	.550-04	.893-04	.326-04
ZINC	.734-04	.327-04	.532-04
ZIRCONIUM	* .000	* .000	* .000
ANION			
CHLORIDE	.610-05	.952-05	* .000
FLUORIDE	.629-06	.632-06	* .000
CYANIDE	< .262-07	< .218-07	* .000
NITRATE	.183-05	.573-05	* .000
SULFATE	.619-04	.535-04	* .000
AMMONIUM	.128-05	.305-06	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP OUTLET
3 MICRON CYCLONE

TRACE ELEMENT		TEST CONDITION	
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.599-06	< .285-07	.631-07
ARSENIC	.912-05	.702-05	.706-05
BARIUM	.214-03	.930-04	.252-03
BERYLLIUM	.200-05	.133-05	.151-05
BISMUTH	< .428-06	.493-04	< .378-06
BORON	.584-04	.446-04	.479-04
CADMIUM	.827-06	.171-06	.454-06
CHROMIUM	.257-04	.171-04	.151-04
COBALT	.613-05	.370-05	.517-05
COPPER	.130-04	.702-05	.115-04
IRON	.328-02	.114-01	.303-02
LEAD	.185-04	.133-04	.164-04
MANGANESE	.105-03	.693-04	.895-04
MERCURY	< .570-07	< .380-07	< .504-07
MOLYBDENUM	< .428-06	.285-06	.101-05
NICKEL	.171-04	.104-04	.139-04
SELENIUM	.185-06	.569-07	.139-06
TELLURIUM	< .855-07	.380-07	< .757-07
THALLIUM	< .570-04	< .380-04	< .504-04
TIN	.428-07	< .190-06	.126-06
TITANIUM	.841-04	.522-03	.618-03
URANIUM	* .000	* .000	* .000
VANADIUM	.442-04	.465-04	.328-04
ZINC	.969-04	.304-04	.757-04
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP OUTLET
1 MICRON CYCLONE

TRACE ELEMENT				TEST CONDITION		
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY		.841-06		.212-07		.391-06
ARSENIC		.742-05		.636-05		.391-05
BARIUM		.990-04		.119-03		.126-03
BERYLLIUM		.891-06		.890-06		.421-06
BISMUTH	<	.148-06		.242-04	<	.180-06
BORON	*	.000		.636-05		.111-04
CADMIUM		.693-06		.216-06		.331-06
CHROMIUM		.139-04		.110-04		.752-05
COBALT		.242-05		.254-05		.111-05
COPPER		.594-05		.343-05		.331-05
IRON		.119-02		.509-02		.601-03
LEAD		.114-04		.110-04		.752-05
MANGANESE		.544-04		.326-04		.180-04
MERCURY	<	.198-07	<	.170-07	<	.210-07
MOLYBDENUM		.891-06		.254-06		.631-06
NICKEL		.742-05		.594-05		.421-05
SELENIUM	<	.990-08		.170-07	<	.120-07
TELLURIUM	<	.297-07		.212-07	<	.271-07
THALLIUM	<	.198-04	<	.170-04	<	.120-04
TIN		.148-06	<	.848-07		.812-06
TITANIUM		.282-03		.233-03		.156-03
URANIUM	*	.000	*	.000	*	.000
VANADIUM		.277-04		.373-04		.132-04
ZINC		.544-04		.339-04		.451-04
ZIRCONIUM	*	.000	*	.000	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP OUTLET FILTER

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.229-05	.301-06	.333-05
ARSENIC	.179-05	.404-05	.399-05
BARIUM	.195-05	.228-05	.108-04
BERYLLIUM	.948-07	.881-07	.146-06
BISMUTH	< .167-07	.521-06	< .266-07
BORON	* .000	* .000	* .000
CADMIUM	.502-06	.176-06	.545-06
CHROMIUM	.128-05	.881-06	.399-05
COBALT	< .167-07	.301-06	.412-06
COPPER	.725-06	.411-07	.160-05
IRON	.134-03	.308-03	.266-03
LEAD	.368-05	.705-06	.146-05
MANGANESE	.301-08	.176-05	.599-05
MERCURY	< .335-08	.661-08	< .798-08
MOLYBDENUM	.318-05	.257-05	.532-05
NICKEL	.948-06	.411-06	.146-05
SELENIUM	.893-07	.198-07	.239-06
TELLURIUM	.156-07	.734-08	.426-07
THALLIUM	.117-06	.198-06	.109-06
TIN	< .390-07	< .734-07	.266-06
TITANIUM	.781-05	.147-04	.359-04
URANIUM	* .000	* .000	* .000
VANADIUM	.669-05	.103-04	.945-05
ZINC	.301-05	.529-05	.133-04
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP OUTLET
XAD-2 RESIN

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .787-06	.176-05	< .621-06
ARSENIC	< .984-06	< .481-05	< .776-06
BARIUM	.216-03	.361-04	.528-04
BERYLLIUM	< .590-06	< .722-06	< .621-06
BISMUTH	< .590-06	< .120-05	.119-05
BORON	.531-04	.361-03	< .155-04
CADMIUM	< .394-07	.233-05	.466-07
CHROMIUM	.138-04	.529-04	.135-04
COBALT	< .394-04	< .120-04	< .310-04
COPPER	.275-05	< .192-06	< .155-05
IRON	.708-05	.866-03	.978-05
LEAD	< .590-07	< .481-06	< .466-07
MANGANESE	.236-06	.183-04	.667-06
MERCURY	< .984-06	< .168-05	< .776-06
MOLYBDENUM	< .118-04	< .120-04	< .931-05
NICKEL	< .984-05	< .481-06	< .776-05
SELENIUM	.183-04	.106-04	.838-05
TELLURIUM	< .138-05	< .481-06	< .109-05
THALLIUM	.108-04	< .144-05	.822-05
TIN	.275-05	< .192-05	.931-06
TITANIUM	< .590-05	.361-03	< .466-05
URANIUM	* .000	* .000	* .000
VANADIUM	< .118-05	< .962-06	< .776-05
ZINC	< .590-05	< .144-04	< .621-05
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP OUTLET
FIRST IMPINGER

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .581-07	< .106-06	< .616-07
ARSENIC	.959-06	.149-05	.956-06
BARIUM	< .145-04	.602-04	.339-04
BERYLLIUM	< .581-07	< .354-07	.123-07
BISMUTH	< .581-07	< .106-06	.925-07
BORON	.814-03	.920-03	.863-03
CADMIUM	.131-06	.113-05	< .308-08
CHROMIUM	.151-02	.315-02	.105-03
COBALT	.204-04	.315-04	.771-05
COPPER	.436-05	.212-07	.185-05
IRON	.169-02	.117-01	.129-02
LEAD	.169-06	< .354-07	< .616-08
MANGANESE	.186-03	.991-04	.678-04
MERCURY	.581-06	< .708-05	< .308-06
MOLYBDENUM	.108-03	.237-04	.986-05
NICKEL	.640-03	.138-02	.432-03
SELENIUM	.160-04	.145-04	.182-04
TELLURIUM	< .145-06	.142-06	.308-06
THALLIUM	.378-06	< .708-07	.197-06
TIN	.581-06	< .106-05	.616-06
TITANIUM	< .291-03	< .354-06	< .308-03
URANIUM	* .000	* .000	* .000
VANADIUM	.581-06	.389-05	.213-05
ZINC	< .291-04	.389-05	< .308-04
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP OUTLET
2ND & 3RD IMPINGERS

TRACE ELEMENT	TEST CONDITION					
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY		.862-07	<	.104-06	<	.674-07
ARSENIC		.402-06		.519-06		.315-06
BARIUM	*	.000	*	.000	*	.000
BERYLLIUM	*	.000	*	.000	*	.000
BISMUTH	*	.000	*	.000	*	.000
BORON	*	.000	*	.000	*	.000
CADMIUM	*	.000	*	.000	*	.000
CHROMIUM	*	.000	*	.000	*	.000
COBALT	*	.000	*	.000	*	.000
COPPER	*	.000	*	.000	*	.000
IRON	*	.000	*	.000	*	.000
LEAD	*	.000	*	.000	*	.000
MANGANESE	*	.000	*	.000	*	.000
MERCURY	<	.575-05	<	.692-05	<	.674-05
MOLYBDENUM	*	.000	*	.000	*	.000
NICKEL	*	.000	*	.000	*	.000
SELENIUM	*	.000	*	.000	*	.000
TELLURIUM	*	.000	*	.000	*	.000
THALLIUM	*	.000	*	.000	*	.000
TIN	*	.000	*	.000	*	.000
TITANIUM	*	.000	*	.000	*	.000
URANIUM	*	.000	*	.000	*	.000
VANADIUM	*	.000	*	.000	*	.000
ZINC	*	.000	*	.000	*	.000
ZIRCONIUM	*	.000	*	.000	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/J - ESP OUTLET

TRACE ELEMENT		TEST CONDITION	
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.487-05	.240-05	< .458-05
ARSENIC	.232-04	.264-04	.186-04
BARIUM	.115-02	.498-03	.854-03
BERYLLIUM	.625-05	.524-05	.410-05
BISMUTH	< .203-05	.806-04	< .239-05
BORON	.100-02	.137-02	.969-03
CADMIUM	.285-05	.424-05	.162-05
CHROMIUM	.160-02	.326-02	.164-03
COBALT	.774-04	.538-04	.525-04
COPPER	.446-04	.205-04	.354-04
IRON	.105-01	.773-01	.109-01
LEAD	.459-04	.329-04	.333-04
MANGANESE	.577-03	.395-03	.319-03
MERCURY	< .750-05	.159-04	.797-05
MOLYBDENUM	.125-03	.393-04	.268-04
NICKEL	.701-03	.142-02	.474-03
SELENIUM	.348-04	< .252-04	.272-04
TELLURIUM	< .181-05	< .711-06	< .164-05
THALLIUM	< .193-03	< .144-03	< .140-03
TIN	.383-05	< .377-05	< .292-05
TITANIUM	.167-02	.181-02	.196-02
URANIUM	* .000	* .000	* .000
VANADIUM	.135-03	.188-03	.980-04
ZINC	.263-03	.121-03	.224-03
ZIRCONIUM	* .000	* .000	* .000

APPENDIX D-3

TRACE ELEMENT FLOWRATE (μg/DSCM)

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - COAL INLET

TRACE ELEMENT CATION		TEST CONDITION BASELINE		BOOS1		BOOS2
ANTIMONY	<	.200	<	.200	<	.200
ARSENIC		1.70		.900		.900
BARIUM		93.0		60.0		76.0
BERYLLIUM		1.40		1.20		1.20
BISMUTH	<	3.00	<	2.00	<	2.00
BORON	*	.000	*	.000	*	.000
CADMIUM	<	.100+00	<	.100+00	<	.100+00
CHROMIUM		22.0		17.0		16.0
COBALT		4.60		3.50		4.60
COPPER		11.0		11.0		9.80
IRON		.230+05		.260+05		.180+05
LEAD		18.0	<	6.00	<	5.00
MANGANESE		73.0		73.0		52.0
MERCURY		.700-01		.170		.110
MOLYBDENUM		8.70		13.0		8.10
NICKEL		23.0		18.0		12.0
SELENIUM		1.30		1.00		1.20
TELLURIUM	<	.200	<	.200	<	.200
THALLIUM	<	4.00	<	3.00	<	3.00
TIN		2.20		1.80		63.0
TITANIUM		.166+04		.103+04		.132+04
URANIUM	*	.000	*	.000	*	.000
VANADIUM		38.0		60.0		31.0
ZINC		49.0		51.0		43.0
ZIRCONIUM	*	.000	*	.000	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - BOTTOM ASH

TRACE ELEMENT		TEST CONDITION				
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY	<	.600	<	.600	<	.600
ARSENIC	<	3.00	<	8.00	<	3.00
BARIUM		270.		770.		160.
BERYLLIUM		9.00		6.50		7.70
BISMUTH	<	6.00		230.	<	6.00
BORON	<	.100+00		.200		.200
CADMIUM	<	.300-01		.480	<	.300-01
CHROMIUM		75.0		100.		74.0
COBALT		5.00	<	.100+00		2.00
COPPER		60.0		23.0		53.0
IRON		.410+05		.190+06		.430+05
LEAD		34.0		23.0		21.0
MANGANESE		690.		.110+04		970.
MERCURY	<	.600	<	.600	<	.700
MOLYBDENUM	<	6.00	<	3.00	<	.600
NICKEL		54.0		48.0		53.0
SELENIUM		.700		1.00		2.50
TELLURIUM	<	.900		.400	<	.900
THALLIUM	<	400.	<	400.	<	400.
TIN	<	2.00	<	4.00	<	2.00
TITANIUM		.240+04		.510+04		.230+04
URANIUM	*	.000	*	.000	*	.000
VANADIUM		240.		340.		220.
ZINC		150.		310.		190.
ZIRCONIUM	*	.000	*	.000	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP INLET
10 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	5.81	< .959	< 1.31
ARSENIC	81.3	89.5	114.
BARIUM	.407+04	.176+04	.700+04
BERYLLIUM	29.0	41.6	43.7
BISMUTH	< 8.71	.173+04	< 13.1
BORON	.142+04	.144+04	.162+04
CADMIUM	8.42	7.36	9.62
CHROMIUM	.116+04	512.	.109+04
COBALT	102.	157.	192.
COPPER	221.	192.	319.
IRON	.639+05	.448+06	.140+06
LEAD	227.	.320+04	363.
MANGANESE	.241+04	.237+04	.311+04
MERCURY	< 1.45	1.28	< 1.75
MOLYBDENUM	37.8	6.40	30.6
NICKEL	813.	256.	831.
SELENIUM	5.23	2.88	7.44
TELLURIUM	< 1.74	1.92	< 2.62
THALLIUM	< .116+04	< .128+04	< .175+04
TIN	< 2.90	< 6.40	< 4.37
TITANIUM	.128+05	.134+05	.188+05
URANIUM	* .000	* .000	* .000
VANADIUM	639.	.138+04	919.
ZINC	.148+04	768.	.149+04
ZIRCONIUM	* .000	* .000	* .000
ANION			
CHLORIDE	* .000	* .000	153.
FLUORIDE	* .000	* .000	12.7
CYANIDE	* .000	* .000	< .437
NITRATE	* .000	* .000	37.2
SULFATE	* .000	* .000	.114+04
AMMONIUM	* .000	* .000	38.9

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP INLET
3 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	3.65	< 1.17	6.16
ARSENIC	292.	305.	207.
BARIUM	.893+04	.258+04	.778+04
BERYLLIUM	52.8	62.6	38.9
BISMUTH	< 12.2	.133+04	< 9.73
BORON	.276+04	.168+04	.100+04
CADMIUM	19.9	6.26	15.9
CHROMIUM	650.	783.	584.
COBALT	134.	227.	133.
COPPER	329.	294.	269.
IRON	.853+05	.431+06	.713+05
LEAD	528.	705.	519.
MANGANESE	.300+04	.298+04	.305+04
MERCURY	< 1.62	< 1.96	< 1.30
MOLYBDENUM	40.6	23.5	25.9
NICKEL	487.	391.	389.
SELENIUM	5.28	< .391	17.5
TELLURIUM	< 2.44	.783	< 1.95
THALLIUM	< .162+04	< .157+04	< .130+04
TIN	< 4.06	< 7.83	6.48
TITANIUM	.187+05	.188+05	.133+05
URANIUM	* .000	* .000	* .000
VANADIUM	.126+04	.243+04	843.
ZINC	.256+04	.157+04	.357+04
ZIRCONIUM	* .000	* .000	* .000
ANION			
CHLORIDE	* .000	* .000	75.2
FLUORIDE	* .000	* .000	5.84
CYANIDE	* .000	* .000	< .324
NITRATE	* .000	* .000	4.54
SULFATE	* .000	* .000	9.21
AMMONIUM	* .000	* .000	.973

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP INLET
1 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	18.1	< .375	5.61
ARSENIC	168.	187.	143.
BARIUM	.245+04	.325+04	.334+04
BERYLLIUM	20.7	18.7	19.1
BISMUTH	< 3.88	48.7	< 3.58
BORON	426.	437.	465.
CADMIUM	18.1	6.87	11.9
CHROMIUM	388.	337.	286.
COBALT	78.8	85.0	58.4
COPPER	155.	86.2	131.
IRON	.271+05	.162+06	.286+05
LEAD	284.	362.	298.
MANGANESE	.125+04	962.	.143+04
MERCURY	< .517	< .500	< .477
MOLYBDENUM	18.1	7.50	13.1
NICKEL	194.	175.	179.
SELENIUM	1.94	< .125	2.98
TELLURIUM	< .775	.375	< .716
THALLIUM	< 517.	< 500.	< 477.
TIN	5.17	3.75	11.9
TITANIUM	.853+04	.837+04	.799+04
URANIUM	* .000	* .000	* .000
VANADIUM	620.	.112+04	453.
ZINC	.155+04	1000.	.131+04
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP INLET FILTER

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	126.	21.3	99.3
ARSENIC	94.7	254.	44.4
BARIUM	308.	135.	144.
BERYLLIUM	5.92	6.43	4.18
BISMUTH	< .789	60.9	< .522
BORON	* .000	* .000	* .000
CADMIUM	22.1	10.5	15.4
CHROMIUM	98.7	40.6	44.4
COBALT	7.89	32.1	7.31
COPPER	32.8	50.7	21.2
IRON	.395+04	.233+05	.418+04
LEAD	31.6	54.1	25.1
MANGANESE	166.	112.	.653-01
MERCURY	< .237	< .203	< .157
MOLYBDENUM	193.	173.	133.
NICKEL	78.9	23.3	13.6
SELENIUM	3.95	1.25	4.70
TELLURIUM	1.50	1.12	1.23
THALLIUM	4.74	12.9	2.61
TIN	3.95	< 3.38	15.7
TITANIUM	553.	.129+04	601.
URANIUM	* .000	* .000	* .000
VANADIUM	434.	677.	256.
ZINC	213.	372.	470.
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP INLET
XAD-2 RESIN

TRACE ELEMENT		TEST CONDITION	
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< 2.95	* .000	< 2.03
ARSENIC	< 3.54	* .000	< 2.03
BARIUM	147.	* .000	529.
BERYLLIUM	< 2.95	* .000	< 2.03
BISMUTH	< 2.36	* .000	< 1.22
BORON	230.	* .000	< 81.4
CADMIUM	< .118	* .000	.366
CHROMIUM	82.5	* .000	22.8
COBALT	< 118.	* .000	73.2
COPPER	< .236	* .000	7.32
IRON	22.4	* .000	936.
LEAD	8.25	* .000	5.70
MANGANESE	10.0	* .000	1.38
MERCURY	< 4.13	* .000	< 2.44
MOLYBDENUM	< 53.1	* .000	< 28.5
NICKEL	< 41.3	* .000	< 24.4
SELENIUM	< 1.77	* .000	1.63
TELLURIUM	< 4.13	* .000	< 2.85
THALLIUM	31.8	* .000	19.1
TIN	< 2.36	* .000	< 1.22
TITANIUM	< 23.6	* .000	< 16.3
URANIUM	* .000	* .000	* .000
VANADIUM	< 53.1	* .000	< 32.6
ZINC	< 17.7	* .000	< 12.2
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP INLET
FIRST IMPINGER

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .157	* .000	< .156
ARSENIC	2.52	* .000	2.11
BARIUM	< 39.3	* .000	86.0
BERYLLIUM	< .157	* .000	.391-01
BISMUTH	.236	* .000	.446
BORON	.228+04	* .000	.235+04
CADMIUM	< .551-02	* .000	.375
CHROMIUM	.378+04	* .000	305.
COBALT	42.5	* .000	29.7
COPPER	78.6	* .000	55.5
IRON	456.	* .000	.446+04
LEAD	1.73	* .000	.164+04
MANGANESE	393.	* .000	328.
MERCURY	2.36	* .000	< .782
MOLYBDENUM	267.	* .000	180.
NICKEL	.228+04	* .000	86.0
SELENIUM	47.2	* .000	52.4
TELLURIUM	< .393	* .000	< .313
THALLIUM	.944	* .000	.672
TIN	5.90	* .000	< .782
TITANIUM	< 786.	* .000	< 782.
URANIUM	* .000	* .000	* .000
VANADIUM	6.92	* .000	10.2
ZINC	228.	* .000	180.
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP INLET
2ND & 3RD IMPINGERS

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .254	* .000	< .170
ARSENIC	< .423	* .000	.679
BARIUM	* .000	* .000	* .000
BERYLLIUM	* .000	* .000	* .000
BISMUTH	* .000	* .000	* .000
BORON	* .000	* .000	* .000
CADMIUM	* .000	* .000	* .000
CHROMIUM	* .000	* .000	* .000
COBALT	* .000	* .000	* .000
COPPER	* .000	* .000	* .000
IRON	* .000	* .000	* .000
LEAD	* .000	* .000	* .000
MANGANESE	* .000	* .000	* .000
MERCURY	< .507	* .000	< 17.0
MOLYBDENUM	* .000	* .000	* .000
NICKEL	* .000	* .000	* .000
SELENIUM	* .000	* .000	* .000
TELLURIUM	* .000	* .000	* .000
THALLIUM	* .000	* .000	* .000
TIN	* .000	* .000	* .000
TITANIUM	* .000	* .000	* .000
URANIUM	* .000	* .000	* .000
VANADIUM	* .000	* .000	* .000
ZINC	* .000	* .000	* .000
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP INLET

TRACE ELEMENT				TEST CONDITION		
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY		157.	<	23.8	<	115.
ARSENIC		643.		836.		514.
BARIUM		.159+05		.773+04		.189+05
BERYLLIUM		112.		129.		108.
BISMUTH	<	28.2		.317+04	<	28.6
BORON		.712+04		.356+04		.552+04
CADMIUM		68.6		31.0		53.6
CHROMIUM		.616+04		.167+04		.234+04
COBALT		483.		501.		494.
COPPER		816.		622.		804.
IRON		.181+06		.106+07		.250+06
LEAD		.108+04		.432+04		.285+04
MANGANESE		.724+04		.642+04		.791+04
MERCURY	<	10.8		3.94	<	23.9
MOLYBDENUM		610.		210.		411.
NICKEL		.390+04		846.		.152+04
SELENIUM		65.3		4.65		86.6
TELLURIUM	<	11.0		4.19	<	9.67
THALLIUM	<	.334+04	<	.336+04	<	.355+04
TIN	<	24.3	<	21.4	<	40.5
TITANIUM		.413+05		.419+05		.415+05
URANIUM	*	.000	*	.000	*	.000
VANADIUM		.301+04		.560+04		.251+04
ZINC		.605+04		.371+04		.703+04
ZIRCONIUM	*	.000	*	.000	*	.000
ANION						
CHLORIDE	*	.000	*	.000		228.
FLUORIDE	*	.000	*	.000		18.5
CYANIDE	*	.000	*	.000	<	.762
NITRATE	*	.000	*	.000		41.7
SULFATE	*	.000	*	.000		.115+04
AMMONIUM	*	.000	*	.000		39.9

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP HOPPER ASH

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .500	< .700	< .500
ARSENIC	< 3.00	20.0	< 3.00
BARIUM	190.	.120+04	59.0
BERYLLIUM	7.40	9.00	6.50
BISMUTH	< 6.00	570.	7.00
BORON	370.	390.	390.
CADMIUM	4.10	1.60	1.40
CHROMIUM	130.	120.	110.
COBALT	< 2.00	78.0	< 2.00
COPPER	48.0	42.0	45.0
IRON	.330+05	.160+06	.280+05
LEAD	62.0	60.0	68.0
MANGANESE	.120+04	.120+04	600.
MERCURY	< .800	< .700	.900
MOLYBDENUM	< 6.00	< 3.00	24.0
NICKEL	150.	46.0	89.0
SELENIUM	1.00	1.00	2.80
TELLURIUM	< .900	< .200	< .900
THALLIUM	< 400.	< 400.	< 400.
TIN	3.00	< 5.00	< 2.00
TITANIUM	.400+04	.540+04	.260+04
URANIUM	* .000	* .000	* .000
VANADIUM	230.	360.	210.
ZINC	210.	260.	150.
ZIRCONIUM	170.	140.	* .000
ANION			
CHLORIDE	23.0	29.2	< 5.20
FLUORIDE	10.1	2.80	2.00
CYANIDE	< .100+00	< .100+00	< .100+00
NITRATE	14.0	5.60	43.5
SULFATE	196.	263.	212.
AMMONIUM	2.30	5.80	5.40

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP OUTLET
10 MICRON CYCLONE

TRACE ELEMENT		TEST CONDITION				
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY		.465		.174	<	.138
ARSENIC		5.53		4.34		4.23
BARIUM		.134+04		373.		.101+04
BERYLLIUM		5.82		4.34		3.73
BISMUTH	<	1.75		10.4	<	1.38
BORON		169.		73.8		82.8
CADMIUM		1.45		.421		.644
CHROMIUM		69.8		52.1		50.6
COBALT		20.4		7.38		18.9
COPPER		39.6		19.5		41.9
IRON		.931+04		.955+05		.152+05
LEAD		26.8		14.8		21.2
MANGANESE		512.		347.		368.
MERCURY	<	.233		.217		.184
MOLYBDENUM		2.91		.868		1.84
NICKEL		57.0		47.7		40.0
SELENIUM		.465	<	.434-01		.782
TELLURIUM	<	.349	<	.434-01	<	.276
THALLIUM	<	233.	<	174.	<	184.
TIN		.582	<	.868	<	.460
TITANIUM		.221+04		.135+04		.225+04
URANIUM	*	.000	*	.000	*	.000
VANADIUM		122.		178.		87.4
ZINC		163.		65.1		143.
ZIRCONIUM	*	.000	*	.000	*	.000
ANION						
CHLORIDE		13.6		19.0	*	.000
FLUORIDE		1.40		1.26	*	.000
CYANIDE	<	.582-01	<	.434-01	*	.000
NITRATE		4.07		11.4	*	.000
SULFATE		138.		107.	*	.000
AMMONIUM		2.85		.608	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP OUTLET
3 MICRON CYCLONE

TRACE ELEMENT		TEST CONDITION				
CATION		BASELINE		BOOS1		BOOS2
ANTIMONY		1.33	<	.567-01		.169
ARSENIC		20.3		14.0		18.9
BARIUM		475.		185.		675.
BERYLLIUM		4.43		2.65		4.05
BISMUTH	<	.950		98.3	<	1.01
BORON		130.		88.9		128.
CADMIUM		1.84		.340		1.22
CHROMIUM		57.0		34.0		40.5
COBALT		13.6		7.37		13.8
COPPER		28.8		14.0		30.7
IRON		.728+04		.227+05		.811+04
LEAD		41.1		26.5		43.9
MANGANESE		234.		138.		240.
MERCURY	<	.127	<	.756-01	<	.135
MOLYBDENUM	<	.950		.567		2.70
NICKEL		38.0		20.8		37.2
SELENIUM		.411		.113		.372
TELLURIUM	<	.190		.756-01	<	.203
THALLIUM	<	127.	<	75.6	<	135.
TIN		.950-01	<	.378		.338
TITANIUM		187.		.104+04		.165+04
URANIUM	*	.000	*	.000	*	.000
VANADIUM		98.1		92.6		87.8
ZINC		215.		60.5		203.
ZIRCONIUM	*	.000	*	.000	*	.000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP OUTLET
1 MICRON CYCLONE

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	1.87	.422-01	1.05
ARSENIC	16.5	12.7	10.5
BARIUM	220.	237.	338.
BERYLLIUM	1.98	1.77	1.13
BISMUTH	< .330	48.2	< .483
BORON	* .000	12.7	29.8
CADMIUM	1.54	.431	.886
CHROMIUM	30.8	22.0	20.1
COBALT	5.38	5.07	2.98
COPPER	13.2	6.84	8.86
IRON	.264+04	.101+05	.161+04
LEAD	25.3	22.0	20.1
MANGANESE	121.	65.0	48.3
MERCURY	< .440-01	< .338-01	< .564-01
MOLYBDENUM	1.98	.507	1.69
NICKEL	16.5	11.8	11.3
SELENIUM	< .220-01	.338-01	< .322-01
TELLURIUM	< .659-01	.422-01	< .725-01
THALLIUM	< 44.0	< 33.8	< 32.2
TIN	.330	< .169	2.17
TITANIUM	626.	465.	419.
URANIUM	* .000	* .000	* .000
VANADIUM	61.5	74.3	35.4
ZINC	121.	67.6	121.
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP OUTLET
FILTER

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	5.08	.600	8.91
ARSENIC	3.96	8.05	10.7
BARIUM	4.34	4.53	28.9
BERYLLIUM	.211	.176	.392
BISMUTH	< .372-01	1.04	< .713-01
BORON	* .000	* .000	* .000
CADMIUM	1.11	.351	1.46
CHROMIUM	2.85	1.76	10.7
COBALT	< .372-01	.600	1.10
COPPER	1.61	.819-01	4.28
IRON	297.	614.	713.
LEAD	8.18	1.40	3.92
MANGANESE	.669-02	3.51	16.0
MERCURY	< .743-02	.132-01	< .214-01
MOLYBDENUM	7.06	5.12	14.3
NICKEL	2.11	.819	3.92
SELENIUM	.198	.395-01	.641
TELLURIUM	.347-01	.146-01	.114
THALLIUM	.260	.395	.292
TIN	< .867-01	< .146	.713
TITANIUM	17.3	29.3	96.2
URANIUM	* .000	* .000	* .000
VANADIUM	14.9	20.5	25.3
ZINC	6.69	10.5	35.6
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP OUTLET
XAD-2 RESIN

TRACE ELEMENT CATION	BASELINE	TEST CONDITION BOOS1	BOOS2
ANTIMONY	< 1.75	3.50	< 1.66
ARSENIC	< 2.18	< 9.58	< 2.08
BARIUM	481.	71.9	141.
BERYLLIUM	< 1.31	< 1.44	< 1.66
BISMUTH	< 1.31	< 2.40	3.20
BORON	118.	719.	< 41.6
CADMIUM	< .874-01	4.65	.125
CHROMIUM	30.6	105.	36.2
COBALT	< 87.4	< 24.0	< 83.1
COPPER	6.12	< .383	< 4.16
IRON	15.7	.173+04	26.2
LEAD	< .131	< .958	< .125
MANGANESE	.524	36.4	1.79
MERCURY	< 2.18	< 3.35	< 2.08
MOLYBDENUM	< 26.2	< 24.0	< 24.9
NICKEL	< 21.8	< .958	< 20.8
SELENIUM	40.6	21.1	22.4
TELLURIUM	< 3.06	< .958	< 2.91
THALLIUM	24.0	< 2.88	22.0
TIN	6.12	< 3.83	2.49
TITANIUM	< 13.1	719.	< 12.5
URANIUM	* .000	* .000	* .000
VANADIUM	< 2.62	< 1.92	< 20.8
ZINC	< 13.1	< 28.8	< 16.6
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP OUTLET
FIRST IMPINGER

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	< .129	< .212	< .165
ARSENIC	2.13	2.96	2.56
BARIUM	< 32.3	120.	90.8
BERYLLIUM	< .129	< .705-01	.330-01
BISMUTH	< .129	< .212	.248
BORON	.181+04	.183+04	.231+04
CADMIUM	.291	2.26	< .825-02
CHROMIUM	.336+04	.628+04	281.
COBALT	45.2	62.8	20.6
COPPER	9.69	.423-01	4.95
IRON	.375+04	.233+05	.347+04
LEAD	.375	< .705-01	< .165-01
MANGANESE	413.	197.	182.
MERCURY	1.29	< 14.1	< .825
MOLYBDENUM	239.	47.3	26.4
NICKEL	.142+04	.275+04	.116+04
SELENIUM	35.5	28.9	48.7
TELLURIUM	< .323	.282	.825
THALLIUM	.839	< .141	.528
TIN	1.29	< 2.12	1.65
TITANIUM	< 646.	< .705	< 825.
URANIUM	* .000	* .000	* .000
VANADIUM	1.29	7.76	5.70
ZINC	< 64.6	7.76	< 82.5
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP OUTLET
2ND & 3RD IMPINGERS

TRACE ELEMENT	TEST CONDITION		
CATION	BASELINE	BOOS1	BOOS2
ANTIMONY	.191	< .207	< .181
ARSENIC	.893	1.03	.843
BARIUM	* .000	* .000	* .000
BERYLLIUM	* .000	* .000	* .000
BISMUTH	* .000	* .000	* .000
BORON	* .000	* .000	* .000
CADMIUM	* .000	* .000	* .000
CHROMIUM	* .000	* .000	* .000
COBALT	* .000	* .000	* .000
COPPER	* .000	* .000	* .000
IRON	* .000	* .000	* .000
LEAD	* .000	* .000	* .000
MANGANESE	* .000	* .000	* .000
MERCURY	< 12.8	< 13.8	< 18.1
MOLYBDENUM	* .000	* .000	* .000
NICKEL	* .000	* .000	* .000
SELENIUM	* .000	* .000	* .000
TELLURIUM	* .000	* .000	* .000
THALLIUM	* .000	* .000	* .000
TIN	* .000	* .000	* .000
TITANIUM	* .000	* .000	* .000
URANIUM	* .000	* .000	* .000
VANADIUM	* .000	* .000	* .000
ZINC	* .000	* .000	* .000
ZIRCONIUM	* .000	* .000	* .000

COAL FIRED HO UTILITY BOILER

TRACE ELEMENT ANALYSIS - MCG/DSCM - ESP OUTLET

TRACE ELEMENT	TEST CONDITION BASELINE	BOOS1	BOOS2
CATION			
ANTIMONY	10.8	4.79	< 12.3
ARSENIC	51.4	52.6	49.8
BARIUM	.255+04	991.	.229+04
BERYLLIUM	13.9	10.4	11.0
BISMUTH	< 4.50	161.	< 6.39
BORON	.222+04	.273+04	.259+04
CADMIUM	6.32	8.45	4.34
CHROMIUM	.355+04	.649+04	439.
COBALT	172.	107.	141.
COPPER	99.0	40.9	94.8
IRON	.233+05	.154+06	.291+05
LEAD	102.	65.6	89.2
MANGANESE	.128+04	788.	855.
MERCURY	< 16.7	31.6	21.4
MOLYBDENUM	278.	78.3	71.8
NICKEL	.156+04	.283+04	.127+04
SELENIUM	77.2	< 50.2	73.0
TELLURIUM	< 4.02	< 1.42	< 4.40
THALLIUM	< 428.	< 286.	< 374.
TIN	8.50	< 7.51	< 7.83
TITANIUM	.370+04	.360+04	.526+04
URANIUM	* .000	* .000	* .000
VANADIUM	301.	375.	262.
ZINC	583.	240.	601.
ZIRCONIUM	* .000	* .000	* .000
ANION			
CHLORIDE	13.6	19.0	* .000
FLUORIDE	1.40	1.26	* .000
CYANIDE	< .582-01	< .434-01	* .000
NITRATE	4.07	11.4	* .000
SULFATE	138.	107.	* .000
AMMONIUM	2.85	.608	* .000

APPENDIX E
BIOASSAY RESULTS

APPENDIX E
BIOASSAY RESULTS

Bioassay tests were performed on several samples taken during the BOOS 2 test. A list of samples taken, and the tests performed on those samples, is shown in Table E-1. The results of the assays performed on each sample are discussed in the following paragraphs.

E.1 BOOS 2 BOTTOM ASH

E.1.1 Ames Assay

The test compound was examined for mutagenic activity in a series of *in vitro* microbial assays employing *Salmonella* indicator organisms. The compound was tested directly and in the presence of liver microsomal enzyme preparations from Aroclor-induced rats.

The compound was tested over a series of concentrations for mutagenic activity and toxicity. The dose range employed for the evaluation of this compound was from 0.1 mg to 10 mg per plate.

The test material did not exhibit toxicity with any of the strains employed in this assay.

The results of the tests conducted on the compound in the absence of a metabolic activation system were all negative.

The results of the tests conducted on the compound in the presence of a rat liver activation system were all negative.

The test compound did not demonstrate genetic activity in any of the assays conducted in this evaluation and was considered not mutagenic under these test conditions.

E.1.2 Rabbit Alveolar Macrophage Cytotoxicity Assay

The test material was placed in a porcelain mortar and ground by pestle to a very fine powder. Then about 24 mg of powder was placed in 0.1 ml DMSO and sonicated. After sitting for about two hours to sterilize and leach the material, the suspension was diluted with growth medium and

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TABLE E-1. CRIST BIOASSAY

Sample	Salmonella Mutageniaty (Ames)	Rabbit Alveolar Macrophage (RAM)	Rat Oral Toxicity	Algal Bioassay	Fish Toxicity
Boiler Bottom Ash	X	X	X	X	X
ESP Hopper Ash	X	X	X	X	X
SASS Train (10 µm + 3 µm particles)	X	X	-	-	-
SASS Train (1 µm + filter)	X	X	-	-	-

sonicated briefly. The concentrations applied to the cell cultures ranged from 1000 μg/ml to 3 μg/ml. The negative control cultures received medium without added DMSO since the maximum DMSO concentration in the test cultures was only 0.42 percent and this decreased with successive dilutions of the test material.

None of the five assay parameters yielded EC50 values below 1000 μg/ml. At the maximum concentration of 1000 μg/ml, all the assay parameters were still approximately 90 percent of the negative control values. Therefore, the test material is classified as having nondetectable toxicity to the macrophage cells.

E.1.3 Acute Oral Toxicity Assays

The oral LD50 value of the test material was greater than 10,000 mg/kg for both male and female rats.

E.2 BOOS 2 BOTTOM ASH SLURRY

E.2.1 Fathead Minnow Acute Toxicity Assay

The 96 hour LC_{50} for BOOS 2 boiler bottom ash to fathead minnows is greater than 1000 mg/l. This value is based upon nominal concentrations of the chemical in soft reconstituted water.

E.2.2 Algal Assay

The alga *Selenastrum capricornutum* was exposed to nominal concentrations of boiler bottom ash for 21 days. Data subjected to one way analysis of variance show that the five test treatments and the control are statistically the same 50 percent of the exposure time. As specific growth rates slowed, treatment differences appeared, but at no time was growth inhibited (compared to the control) due to presence of the test material, precluding calculation of an EC50 value. In addition, at no time did growth in any treatment significantly exceed growth in the control. Maximum specific growth rates were obtained during days one to four and maximum cell numbers on day 17.

E.3 ESP HOPPER ASH

E.3.1 Ames Assay

The test compound was examined for mutagenic activity in a series of *in vitro* microbial assays employing *Salmonella* indicator organisms. The compound was tested directly and in the presence of liver microsomal enzyme preparations from Aroclor-induced rats.

The compound was tested over a series of concentrations for mutagenic activity and toxicity. The dose range employed for the evaluation of this compound was from 0.01 mg to 10 mg per plate.

The test compound did not exhibit toxicity with any of the strains employed in this assay.

The results of the tests conducted on the compound in the absence of a metabolic activation system were all negative. A repeat test was conducted with TA-1537 because of contamination observed on the bacterial complete plates in the initial assay. The repeat test was also negative.

The results of the tests conducted on the compound in the presence of a rat liver activation system were all negative.

The nonactivation and activation tests were repeated with TA-100 because of low solvent controls. The repeat tests were also negative.

The test compound did not demonstrate genetic activity in any of the assays conducted in this evaluation and was considered not mutagenic under these test conditions.

E.3.2 Rabbit Alveolar Macrophage Cytotoxicity Assay

About 24 mg of test material was placed into 0.1 ml DMSO and sonicated. After sitting for about two hours to sterilize and leach the material, the suspension was diluted into growth medium and applied to the cell cultures at a maximum concentration of 1000 μg/ml. The negative control cultures received medium without added DMSO since the maximum DMSO concentration in the test cultures was only 0.42 percent and this decreased with successive dilutions of the test material.

None of the five assay parameters yielded EC50 values below 1000 μg/ml. Therefore, the test material is classified as having nondetectable toxicity to the macrophage cells. However, all assay parameters (particularly ATP and ATP/10^6 cells) were observed to decrease relative to the negative control for concentrations of test material greater than about 300 μg/ml.

E.3.3 Rat Acute Oral Toxicity Assay

The oral LD50 value of the test material is judged to be greater than 10,000 mg/kg for both male and female rats.

E.3.4 Fathead Minnow Acute Toxicity Assay

The 96 hour LC$_{50}$ to fathead minnows is greater than 1000 mg/l. This value is based upon nominal concentrations of the chemical in soft reconstituted water.

E.3.5 Algal Assay

The alga Selenastrum capricornutum was exposed to nominal concentrations of ESP hopper ash for 22 days. Data subjected to a logarithmic analysis of variance for the entire test period shows a statistical similarity between the nominal test concentrations of 100, 180, 320, 560 and 1000 mg/l throughout the exposure period. At no time did the test material impede algal growth, compared to the control, control productivity being 27 to 39 percent lower than that of the test treatments.

E.4 BOOS 2 COMBINED SASS 1 μm AND FILTER FLYASH FROM ESP OUTLET

E.4.1 Ames Assay

The test compound was examined for mutagenic activity in a series of *in vitro* microbial assays employing Salmonella in the presence of liver microsomal enzyme preparations from Aroclor-induced rats.

The compound was tested over a series of concentrations for mutagenic activity and toxicity. The dose range employed for the evaluation of this compound was from 0.01 mg to 10 mg per plate. The test compound did not exhibit toxicity with any of the strains employed in this assay.

The results of the tests conducted on the compound in the absence of a metabolic activation system were all negative.

The results of the tests conducted on the compound in the presence of a rat liver activation system were all negative.

The activation and nonactivation tests were repeated with TA-100 because of low solvent controls. The repeat tests were also negative.

The test compound did not demonstrate genetic activity in any of the assays conducted in this evaluation and was considered not mutagenic under these test conditions.

E.4.2 Rabbit Alveolar Macrophage Cyclotoxicity Assay

The test material was supplied as a fine brown powder cake on a glass fiber filter that had been sectioned into quarters. A sample was removed by gently scraping and tapping the surface of the caked material; the glass filter fibers were not disturbed in this process. About 24 mg of test material was then placed in 0.1 ml of DMSO and sonicated. After sitting for about 2 hours to sterilize and leach the material, the suspension was diluted into growth medium and applied to the cell cultures at concentrations from 1000 μg/ml to 3 μg/ml. The negative control cultures received medium without added DMSO since the maximum DMSO concentration in the test cultures was only 0.42 percent and this decreased with successive dilutions of the test material.

All of the assay parameters except total cellular protein yielded EC50 values in the 100 μg/ml to 1000 μg/ml concentration range. Therefore, the test material is classified as having low toxicity. The most responsive parameter was ATP content, which yielded an EC50 value (190 μg/ml) near the low end of the low toxicity region. The ATP per 10^6 total cells was similar because most of the cells remained intact during the treatment period. Hence, the cellular protein remained high and did not indicate an EC50 value. The viability of the remaining cells was affected by the test material, however. Thus, the viability index decreased with increasing doses and indicated a toxicity similar to that provided by the ATP measurement.

E.5 BOOS 2 COMBINED SASS 10 μm AND 3 μm FLYASH FROM ESP OUTLET

E.5.1 Ames Assay

The test compound was examined for mutagenic activity in a series of *in vitro* microbial assays employing *Salmonella* in the presence of liver microsomal enzyme preparations from Aroclor-induced rats.

The compound was tested over a series of concentrations for mutagenic activity and toxicity. The dose range employed for the evaluation of this compound was from 0.01 mg to 10 mg per plate.

The test compound did not exhibit toxicity with any of the strains employed in this assay.

The results of the tests conducted on the compound in the absence of a metabolic activation system were all negative. A repeat test was conducted with TA-100 because of low unacceptable solvent control values in the initial assay. The repeat test was also negative.

The results of the tests conducted on the compound in the presence of a rat liver activation system were all negative. The test was repeated with TA-100 because of low unacceptable solvent control values in the initial assay. The repeat test was also negative.

The test compound did not demonstrate genetic activity in any of the assays conducted in this evaluation and was considered not mutagenic under these test conditions.

E.5.2 Rabbit Alveolar Macrophage Cytotoxicity Assay

About 24 mg of test material was placed in 0.1 ml DMSO and sonicated. After sitting for about two hours to sterilize and leach the material, the suspension was diluted into growth medium and applied to the cell cultures at concentrations from 1000 μg/ml to 3 μg/ml. The negative control cultures received medium without added DMSO since the maximum DMSO concentration in the test cultures was only 0.42 percent and this decreased with successive dilutions of the test material.

None of the five assay parameters yielded EC50 values below 1000 μg/ml. Therefore, the test material is classified as having nondetectable toxicity to the macrophage cells. However, some disruption of the cells appeared to occur at the highest tested concentration of 1000 μg/ml, since the viability index, total protein, and total ATP were slightly reduced. About 80 percent of the cells survived without any significant change in ATP content per cell or viability.

The test material is evaluated as having nondetectable toxicity in the Rabbit Alveolar Macrophage Cytotoxicity. The EC50 values for all assay parameters were greater than 1000 μg/ml.